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See half-page Advertisement, page 66, Aug. 29.

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Practice in the Laboratories, Drawing Office, Workshop and Field.
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Principal: CHARLES COLES, B.Sc. (Lond.)

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Head of Department:
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Session 1924-25.
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A Two Years' Course for apprentices and others, with facilities for practical experience in the Summer Term.
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City Hall, Cardiff. F 688

Battersea Polytechnic,

London, S.W.11.
Principal ROBERT H. PICKARD, D.Sc., F.R.S.
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Heat Engines.
Theory of Machines and Machine Design.
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Electrical Power and Transmission.
Electrical Machinery and Design.
Electric Traction.
Telegraphy and Telephony.
Electrical Installation Work.
Fee for London students for approved course, 30/- per session.
Session commences Monday, September 22nd.
Entrance examination to Day Technical College commences Tuesday, September 16th.
Enrolments for Evening Classes commences Wednesday, September 17th. F 722

University of London.

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Professor A. H. JAMESON, M.Sc., M.Inst.C.E., Civil Engineering. (Dean).
C. H. LOBBAN, B.Sc., A.M.Inst.C.E., Senior Lecturer.
Professor E. WILSON, M.Inst.C.E., M.I.E.E., Electrical Engineering.
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The Courses in the above Departments extend over three or four years and prepare students to become specialists in one or other of these branches of Applied Science.
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The LECTURE COURSES commence OCTOBER 1st, 1924.
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Westminster Technical Institute,

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(Telephone—Victoria 5755.)
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PROFESSIONAL and POST-GRADUATE EVENING COURSES in:
Civil and Structural Engineering, including Reinforced Concrete Design, Steel Frame Buildings Design, Hydraulics, Surveying, Specifications and Quantities, Drawing and Mathematics.
The courses provide adequate preparation for the examinations of the Institute of Civil Engineers; the Institution of Structural Engineers, etc.
The Institute will reopen on 15th September, 1924. Apply for prospectus to the PRINCIPAL.
Students living in Middlesex are admitted at London fees.
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Offers must be addressed to THE AGENT GENERAL FOR TASMANIA, Australia House, Strand, London, W.C. 2, to be received by him up to and including 30th September next. F 659

COUNTY BOROUGH OF SOUTHAMPTON.
RECONSTRUCTION OF COBDEN BRIDGE IN STEEL.

Tenders are Invited for the

RECONSTRUCTION of the above mentioned BRIDGE, having five spans of about 75 ft. each including the provision of a temporary bridge, approaches and all incidental works.
Drawings of the proposed works can be seen at the office of the Engineer of the work, Mr. H. W. FITZSIMONS, B.Sc., M.Inst.C.E., 39, Victoria Street, Westminster. Copies of the Specification, Bill of Quantities and Form of Tender are to be obtained from the Engineer's Office on payment of Five Guineas, which sum will be returned upon receipt of a *bona-fide* Tender and the return of all documents.
Sealed Tenders, endorsed "Cobden Bridge, Steel," must be sent to the Town Clerk, Southampton, not later than Ten o'clock in the forenoon on Monday, the 15th day of September, 1924.
The Corporation do not undertake to accept either the lowest or any Tender.
R. R. LINTHORNE, Town Clerk.
25th August, 1924. F 663

COUNTY BOROUGH OF SOUTHAMPTON.
RECONSTRUCTION OF COBDEN BRIDGE IN REINFORCED CONCRETE.

Tenders are Invited for the

RECONSTRUCTION of the above-mentioned BRIDGE having five spans of about 75ft. each including the provision of a temporary bridge, approaches and all incidental works.
Drawings of the proposed works can be seen at the office of the Engineer for the work, Mr. H. W. FITZSIMONS, B.Sc., M.Inst.C.E., 39, Victoria Street, Westminster. Copies of the Specification, Bill of Quantities and Form of Tender are to be obtained from the Engineer's Office on payment of Five Guineas, which will be returned on receipt of a *bona fide* Tender and return of all documents.
Sealed Tenders, endorsed "Cobden Bridge, Concrete," must be sent to the Town Clerk, Southampton, not later than Ten o'clock in the forenoon on Monday, the 15th day of September, 1924.
The Corporation do not undertake to accept either the lowest or any Tender.
R. R. LINTHORNE, Town Clerk.
25th August, 1924. F 662

METROPOLITAN BOROUGH OF ISLINGTON.

The Islington Borough Council invite

Tenders for the Manufacture,

SUPPLY and ERECTION at their Electric Power Station, 60, Eden Grove, Holloway, London, N.7, of a WATER TUBE BOILER, with the necessary Oil Fuel Installation, Draught System, Flues, Steampiping, and other accessories, and the Dismantling and Removal of Four Water Tube Boilers.
Forms of Tender, Specification and Plans can be obtained on and after the 12th September next, upon application to the Borough Electrical Engineer, 60, Eden Grove, London N.7.
Tenders, endorsed "Tender for Boiler," must be delivered to the undersigned not later than NOON on FRIDAY, OCTOBER 17th, 1924.
By Order, C. G. E. FLETCHER, Town Clerk.
Municipal Offices, Tyndale Place, Upper Street, London N.1.
August 30th, 1924. F 748

STATE ELECTRICITY COMMISSION OF VICTORIA.
Melbourne, Victoria, AUSTRALIA.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Yallourn Power Scheme.
Copies of Tender Form and Specification will be available upon application to:—
AGENT-GENERAL FOR VICTORIA, Melbourne Place, Strand, London, W.C. 2.

SPECIFICATION No. 24/88—
66,000 VOLT TRANSFORMERS, INDUCTION REGULATORS AND ACCESSORIES.
CHARGE:—£2 2s. for the first three copies of Tender Form, Conditions of Contract and Specification complete. This charge will be returned on receipt of a *bona fide* Tender. A fourth copy, and any further copies, will be supplied for the sum of 10s. 6d. each. This charge is not returnable.
PRELIMINARY DEPOSIT:—A Preliminary Deposit of £100 is to be lodged with Tender.
The Specifications may be inspected at the above-mentioned office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne not later than Five p.m., 1st December, 1924.
R. LIDDELOW, Secretary F 752

METROPOLITAN ASYLUMS BOARD.

TO ELECTRICAL ENGINEERS.
The Board invite separate

Tenders for:—

(A) The INSTALLATION of an INTERNAL AUTOMATIC TELEPHONE SYSTEM at Leavesden Mental Hospital, Kings Langley, Herts.
(B) The INSTALLATION of a CENTRAL BATTERY TELEPHONE SYSTEM at the Brook Fever Hospital, Shooter's Hill, Woolwich, S.E.18,

in accordance with the Specifications and Drawings prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Specifications, Drawings, and Forms of Tender may be inspected at the Office of the Board, Victoria Embankment, E.C.4, on and after 10 a.m. on SATURDAY, the 6th SEPTEMBER, and can then be obtained upon payment of a deposit of £1 in respect of each work. The amount of the deposit will be returned only after the receipt of a *bona fide* tender sent in accordance with the instructions on the Form of Tender, and after the Specifications and the Drawings have been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board not later than 2.30 p.m. on WEDNESDAY, 8th OCTOBER, 1924.
G. A. POWELL, Clerk to the Board. F 771

THE MACHINE TOOL AND ENGINEERING EXHIBITION.—I.

TO-DAY at Olympia the second Exhibition organised by the Machine Tool Trades Association since the war, is to be opened by the Right Hon. Lord Askwith. The Exhibition will remain open until the 27th inst. The previous Exhibition was held in 1920 under, as will be remembered, rather exceptional circumstances. There was a boom in trade at the time, and firms had many new products to display. Many of these showed the effect of the lessons learnt in munitions work and mass production, but even then the distinctive leaning in the British machine tool industry to the general purpose machine was a noticeable feature of the assemblage. There still seems to be little sign of change in this regard. There will always be a certain market in heavy tools for particular types of single-purpose machines, while a large number of minor operations can be most effectively performed by small and inexpensive tools either specially designed or readily adapted to a quite limited range of repetition work. The large and complex automatic machines, which involve a very heavy capital expenditure, of the class developed to such an extent in the United States, do not appear to offer much attraction to our designers and manufacturers. It is to be concluded from this that, generally speaking, the market for single-purpose machines is too restricted to warrant manufacturers going to the expense of elaborating designs and patterns for the small number likely to be sold. This may well be the case in the machine tool trades at the present time. Although we heard a great deal about mass production immediately after the close of the munitions period, business practically cut its own throat so shortly after that only a few of the many projects actually materialised, and in most directions it has been since then a matter of keeping a firm's name before inquirers rather than of supplying customers. Under the circumstances it is not surprising that while a few special purpose machines may now and then be designed and built for out-of-the-way jobs, as a general rule the small demand for large mass-production automatics or multiple machines has been met by importation from countries where the domestic requirements have led to these developments.

From what we have seen up till the time of writing the Exhibition, while covering a very interesting range of tools, is not so conspicuous as that of 1920 for actual novelties. The number of new models which will be available for inspection will be found to be considerable, but in many instances these will be seen to be improvements on earlier designs, perhaps with additional refinements, rather than new developments. In some instances, in which firms are striking out on new lines, more originality is naturally to be found, but with business as it has been of late there has been little enough to encourage any speculative expenditure, which may require the lapse of years before any commensurate advantage accrues from it.

Some comment has been heard of the fact that the Association is holding an independent exhibition this year, and did not join forces to make a thoroughly representative display at Wembley. We have often expressed our regret that the Association takes no part in the British Industries Fairs, and on similar grounds we are sorry that the machine tool industry has been represented at the British Empire Exhibition on an altogether inadequate scale. The few tools to be seen there are certainly good models of some of our leading firms' products, but no visitor from abroad could possibly carry away with him, after a visit to the Palace of Engineering, a correct impression of the British tool industry. With the visitors numbered by millions, and the greatest assemblage, at the recent Power Conference, of engineers of the first rank the world has perhaps ever seen, the industry would appear to have missed an extremely valuable opportunity of displaying its wares. The fact that the present show is being held while the Wembley one is still open does not make good the season's loss, for the reasons which have drawn engineers from abroad to London to see the Empire Exhibition largely vanished with the termination of most of the technical conferences.

We cannot, however, in justice ignore the fact that originally the Empire Exhibition was planned for 1923, when the two would not have clashed, and the Association, having, we understand, long previously made its arrangements, could not alter them when the British Empire display was put off till this year. It is also possible that the Association feels that it would not have been feasible without an inordinate expense to stage adequately at Wembley a thoroughly interesting, attractive and comprehensive exhibit, and that a shorter, special exhibition serves its members better. This is a fair argument, but thousands of visitors have undoubtedly been here this year, and are now gone back overseas, who might have been interested to the length of becoming customers had the machine tool exhibits at Wembley been more suitably impressive. Export trade is essential to our existence, and, however well a special show may serve, there is no denying the fact that both the annual Fairs and the great Empire effort of this summer, have been planned with the object of developing such business. However it is perhaps, a little ungracious to criticise a policy which, if it has drawbacks, certainly produces for a short space, at intervals of a few years, probably one of the most instructive exhibitions held. The fact that so many of the machines shown are in motion lends an air of reality to these displays at Olympia which is not attainable in any other instance, and all engineers able to do so can rest assured that if they visit this Exhibition they will find it at once fascinating and instructive.

During the course of the Exhibition we hope to describe a selection of the more interesting machines and other apparatus shown. It is to be understood that in this first article we have neither specially picked out those of greatest interest nor discarded such as might be considered by some to be of lesser importance. In a case of this kind it is manifestly impossible to deal with all the exhibits, even in turn, while many of them, as we have pointed out above, are models with which engineers have for some time been familiar. The selection this week pretends to do no more than embrace a range which we trust will include variety sufficient to interest a wide circle among our readers, based to some degree on the facilities accorded to us in the preparation of the material early for publication.

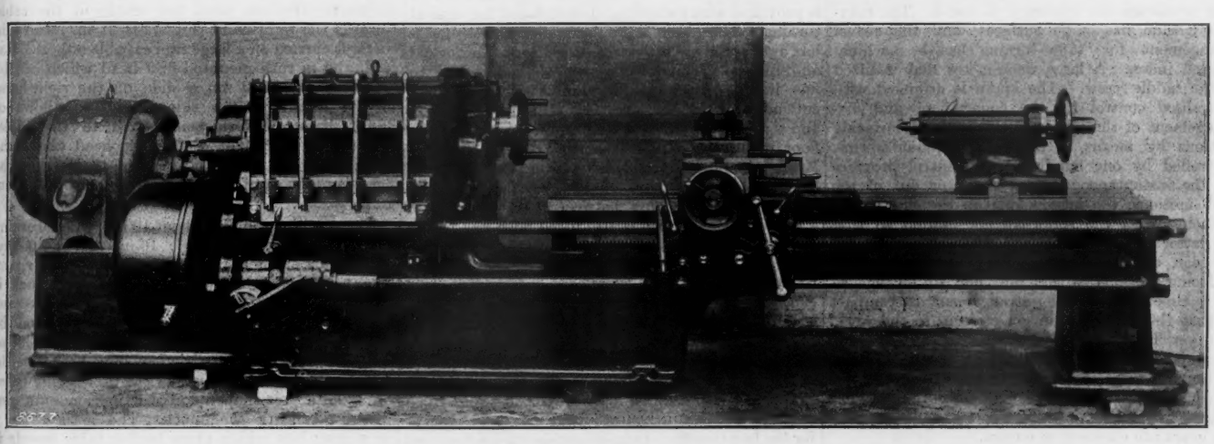


FIG. 1. 10½-INCH CENTRE SLIDING, SURFACING AND SCREW-CUTTING LATHE; MESSRS. JOHN LANG AND SONS, LIMITED.

LATHES.

In dealing with lathes we may well commence with an account of the new 10½-in. centre, sliding, surfacing, and screw-cutting lathe of Messrs. John Lang and Sons, Limited, of Johnstone, near Glasgow. This machine is illustrated in Fig. 1. It is a very powerful machine, and, as would be expected of this firm's products, gives promise of excellent service. The length of bed is 12 ft. and the length between centres is 6 ft. The swing clear of the bed is 21 in., and clear of the saddle 15½ in. The gap allows a swing of 38 in., and in it the work can project 13½ in. from the face plate. The spindle is hollow, having a 2¼-inch hole through it. The front spindle bearing is 6 in. in diameter by 6½ in. long. The machine is driven by a 10 brake horse-power motor running at between 850 and 1,000 revolutions

per minute with reduction to give 400 revolutions per minute at the driving pulley. The spindle speeds obtainable are 12 in number, ranging from 6 to 175 revolutions per minute, while four feeds per revolution of the spindle are also provided, viz., $\frac{1}{8}$ in., $\frac{1}{16}$ in., $\frac{1}{24}$ in., and $\frac{1}{32}$ in.

The bed is of Messrs. Lang's narrow guide type. It is of 20-in. width on the face and 16⅜-in. width of body, and has a depth of 13 in. The design gives great rigidity for heavy cutting. The fast headstock embodies a number of interesting features. We have already noticed that a range of 12 speeds is obtainable. A large taper cone clutch is provided on the fastest running shaft, and a ferodo-lined brake. All levers, which are interlocked, actuate the clutch and brake before changing gears. The sliding gears are hardened and work on castellated shafts. The free position of the spindle is obtained by means of the lever nearest the operator. There are no friction clutches on slow-running shafts and no gears are in mesh except when transmitting power. A plate on the front of the headstock shows the lever positions for all spindle speeds.

The gear-box gives four different sliding or surfacing feeds which may be changed or reversed while running. Four screws may be cut, any one of the pitches being obtainable without stopping the lathe. By means of change wheels other pitches are obtainable, four being derived from each combination of change wheels. The alteration of screw-cutting change wheels does not affect the sliding and surfacing feeds, which remain constant.

The saddle has a longitudinal guide of a length about eight times the width, in order to reduce to a minimum the tendency to twist. The compound slide has large surfaces, and the swivel arrangement for taper-turning has a machine-divided index. A large micrometer dial is fitted to the saddle-screw. The apron is arranged with centralised control for the engagement and disengagement of the self-acting sliding and surfacing motions by means of separate drop-out worms, controlled by one handle. This control provides for the instantaneous throwing in or out of the feed motions, the interlocking of the sliding and surfacing with the screw-cutting motion so that the latter cannot be engaged while the others are in gear, and the interlocking of the sliding and surfacing motions so that only one can be engaged at a time. The whole arrangement is compact so that the operator can get close in to the work, and yet have all control handles within reach. An indicator is fitted to facilitate the engagement of the nut with the lead screw when cutting the threads listed on the change wheel plate. The tailstock has side adjustment for taper-turning. All gears are enclosed in covers.

The machine is arranged for direct motor drive, the motor being carried on a stool bolted to the lathe bed. The reduction gears between the motor and headstock are enclosed in an oil-tight case. The pinion shaft coupled to the armature shaft is carried in an outer ball-bearing.

Messrs. Lang's exhibit also includes a 2 ft. 6 in. cr. surfacing and boring lathe of their standard design, with four-step cone pulley belt drive and gears by which 12 spindle speeds may be obtained with four feeds per revolution of spindle. The saddle, which can be moved along the bed by hand ratchet or by power, is provided with two slide rests, both arranged for taper-turning and with independent self-acting surfacing feeds. The cone pulley is fitted with a brake for stopping the spindle quickly.

Fig. 2, Plate XXVIII, with this week's issue of ENGINEERING, shows an 18½-in. centre lathe exhibited by the Selson Engineering Company, Limited, Coventry. This machine has a bed 25 ft. long, and can take work 17 ft. long between the centres. The bed is very massive, being 25 in. wide and 17 in. deep. The clear height of centres over saddle is 14½ in., while the gap allows a swing of 62 in., the clear width available in the gap being 21 in. There are sixteen spindle speeds, ranging from 2 r.p.m. to 128 r.p.m., the drive being from a pinion to a gear fixed at the back of the face-plate. The headstock is of forged steel. The spindle, which has a 5½ in. diameter hole through it, is carried in parallel bearings of gunmetal, with ring oilers. The front bearing is 8 in. in diameter by 10 in. long, and the back one 6½ in. in diameter by 6½ in. long. The speed levers are interlocked so that they cannot be placed in incorrect positions.

Six feeds are available, ranging from 8 to 55 cuts per inch. The feed-shaft diameter is 1¾ in., the lead screw having a diameter of 3 in. Reversing motion for both lead screw and feed shaft is placed on the outside of the headstock. The apron is of the double-wall type, all apron shafts having two bearings. The feed shaft is engaged by a drop worm, which is instantaneous in action. This is interlocked with the double clamp nut to prevent the sliding and screw-cutting motions being engaged together. The feed shaft is fitted with a safety slipping device. The changes of feed may be obtained while the machine is running.

The bed has square edges with a narrow guide for the saddle, in order to eliminate twist and ensure long maintenance of alignment. The tailstock spindle passes through the handwheel, giving full length of bearing for all positions. The machine is driven by motor through a friction clutch, so that speed changes may be obtained without stopping the motor. Messrs. Selson are showing other lathes of a smaller type, to which we shall refer later.

The lathe illustrated in Fig. 3 on the same Plate is one of a couple exhibited by Messrs. C. Redman and Sons, Limited, Halifax. It is a 13-in. centre general purpose lathe, with large hollow spindle, taking bars 4 in. in diameter. The thrust of the spindle is taken on ball-bearings. The quick-change feed-box gives 16 spindle speeds, with a range of from 6·5 r.p.m. to 440 r.p.m. The feeds range from $\frac{1}{4}$ in. to $\frac{1}{16}$ in. per revolution, or finer if desired. The saddle has large bearing surfaces and is provided with swivelling slide indexed for conical turning. The apron is double-walled. Both gear-box and apron are fitted with steel gears, interlocked and foolproof. The lead screw is guaranteed to fine limits. An indicator eliminates the risk of cutting cross-threads. The gap is of large capacity, and the bed, which has wide surfaces, extends to the floor under the gap. The other lathe shown by Messrs. C. Redman and Sons is a 7-in. cr. tool, with cone pulley and change wheels giving 12 spindle speeds ranging between 10·4 r.p.m. and 420 r.p.m. This lathe is also fitted with ball thrust collar to the spindle. This machine is a good, simple and straightforward tool for production or tool-room work. The feeds are interlocked, and generally the machine is of a design and sturdy construction promising good service with low maintenance.

The 3½-in. centre lathe by Messrs. Drummond Brothers, Limited, of Guildford, illustrated in Fig. 4, Plate XXVIII, is similar in design to one we described recently (see ENGINEERING, page 67 *ante*), except for the fact that the example now shown is a long-bed model. One of the short-bed patterns is also to be seen at the firm's stand. The long-bed pattern takes work 2 ft. 4 in. long between centres. The latter is shown on a stand for countershaft drive. Having so recently described this machine, we must refer our readers to our previous article for further particulars of the design, except that we may draw particular notice to the form of tool-holder now fitted to these lathes. Messrs. Drummond's exhibit further includes a 7-in. centre, sliding, surfacing and screw-cutting lathe taking work 3 ft. 9 in. between centres, with face-plate 18 in. in diameter and giving 21-in. swing in the gap. This has the typical Drummond type of bed, combining the narrow guide of the American type with the flat English type of guide. Another 7-in. lathe shown is designed specially for tool-room work, all essential parts being guaranteed to definite fine limits and the errors recorded. A number of attachments for Drummond lathes, as, for instance, for milling and gear-cutting, are also shown with the tools exhibited. Two 4-in. circular bed lathes for model making also form part of the firm's display, which will prove quite as attractive as usual to the users of the smaller types of machine.

BORING MILLS AND VERTICAL LATHES.

Messrs. Webster and Bennett, Limited, of Foleshill, Coventry, who specialise in boring mills and vertical lathes, have a very interesting exhibit of four machines of this class. Two of these are quite new patterns, the other two being of designs which have been among the firm's standards for the past few years. One of them, a 48-in. mill, is similar to a 42-in. machine which was illustrated in our columns (*see* vol. cx, page 305) when first brought out at the time of the exhibition of 1920. The 48-in. machine is of the duplex type which originated with Messrs. Webster and Bennett. These machines, having independently driven tables, have a capacity of very extended range, and are capable of efficient operation simultaneously on work of widely differing diameters, using maximum speeds and feeds. The single mill exhibited is a 30-in. machine, and is virtually a replica of the right half of the duplex pattern, with, necessarily, some modifications. These machines are well known to engineers and have a deservedly high reputation. Machines of the single type are made from 20 in. in diameter to 36 in. in diameter, while the standard duplex machines run from 20 in. to 48 in. in diameter.

The two new Webster and Bennett tools are illustrated in Figs. 5 to 10 on Plate XXIX and pages 311 and 312. They consist of a 36-in. vertical turret lathe, and a 42-in. vertical boring and turning mill with two heads. The turret lathe is illustrated in Fig. 5, Plate XXIX and Figs. 7 and 8, page 311. The machine introduces various departures from the firm's usual pattern of boring mill, chief of which are the side head and the elevating cross slide, the boring head saddle traversing, in the standard "W and B" mill, on a fixed cross slide. The vertical lathe under notice will take work up to 38 in. in diameter, admitting a height of 35 in. under the turret, and 27 in. under the cross slide. The vertical feed of the turret is 26 in., while the horizontal traverse from the centre of the table towards the right-hand (Fig. 7) is 21 in. The side turret is carried on a large ram capable of horizontal feed, and in turn mounted in a head which can be traversed vertically on a slide on the right hand of the machine. The side head also allows of 38-in. diameter work being fixed to the table. The maximum height of the side head above the table is 16 in., while the vertical traverse of the head is 20 in. and the horizontal feed of the ram 20 in. also.

The machine requires about 10 h.p. when working at full capacity, the single 16-in. driving pulley, at the back of the bed, being designed for 500 r.p.m. The width of belt is 5 in. The table chuck is provided with four independent reversible jaws actuated by protected screws. It is driven by large diameter spur gears of high-tensile steel. The chuck spindle is carried in long bearings, the downward and side thrusts of the table being taken on a large vee-shaped anti-friction pressure ring directly beneath the chuck. The main drive is to a gear box which gives twelve table speeds in geometrical progression. These are controlled by levers brought in a group to the front of the machine. The speeds are interlocked and cannot be changed until the driving pulley is declutched. Declutching automatically brings a brake into action, this being released on clutching in again. A friction clutch is provided on the first motion shaft. The gears are of nickel chrome forgings, heat treated to give 100 tons tensile strength and a high Izod figure. A special form of tooth is used, allowing of fine pitches and small diameters.

The cross slide has power elevating motion. The main turret slide is balanced by an overhead spring. Setting faces are provided to set the turret central with the chuck when boring. The swivel is graduated in degrees of taper boring or turning. The main turret has five faces for special tools. The turret and caps are bored in position. The tool holders are keyed into the turret caps. The dividing mechanism is hardened and finished by grinding. There are 12 feeds for the main turret, vertically, horizontally or at an angle. They are positive, fitted with ball thrusts, and are reversible. Feed trips are provided for the main head, actuated by drop worms, arranged for very fine adjustments. Finely graduated dials facilitate setting of the stops, &c.

The side turret is rectangular and is positively locked in four positions. Protection is arranged to prevent dirt getting under its seating. The side head is balanced by spring; it is very robust and is carried on a very heavy slide, so that it is capable

36-IN. VERTICAL TURRET LATHE AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. WEBSTER AND BENNETT, LIMITED, ENGINEERS, COVENTRY.

Fig. 7.

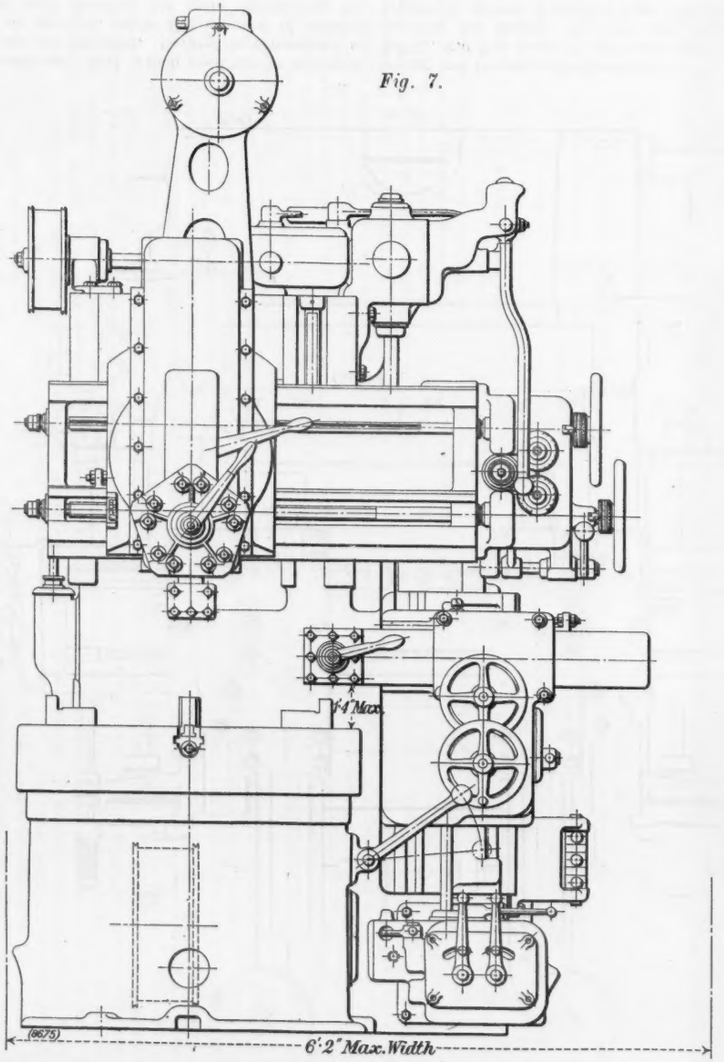
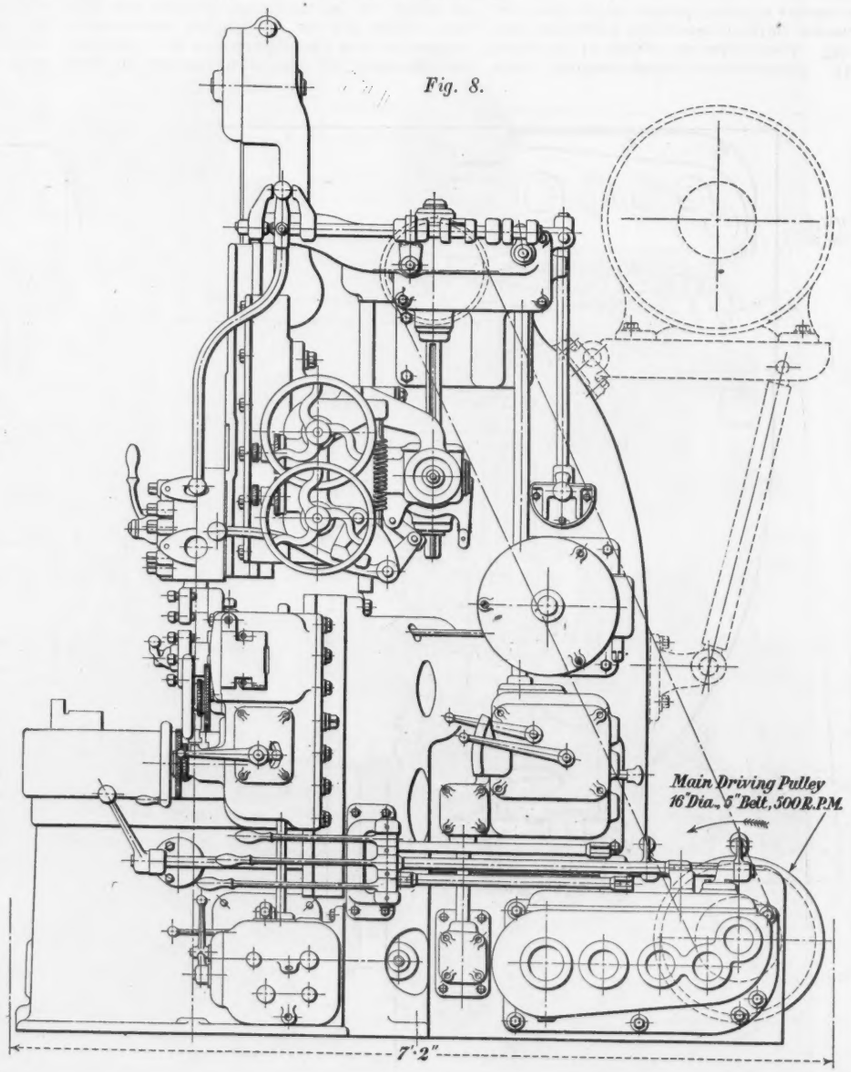


Fig. 8.



of maximum cuts with the highest quality tool steel, without vibration. The slide gives support as close up to the turret as possible. The side head has 12 feeds horizontally and vertically, and independent of the feeds of the main turret. In both cases safety clutches are fitted to the feed gears to prevent damage; all are interlocked. Hand adjustments are made by large-diameter hand wheels permanently locked to the shafts and screws. Rapid-power traverse is instantly available for all motions, controlled and interlocked with the positive feeds by means of a special lever. The main bearings and driving gears are automatically lubricated with filtered oil. Observation tubes are provided so that the correct functioning of the lubrication system can be constantly checked. Sight feed and oil-well lubricators are also furnished.

The general characteristics of the "W. and B." designs are embodied in this tool. There are no loose spanners or handles. Every control has its

42-IN. DOUBLE-RAM BORING MILL AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. WEBSTER AND BENNETT, LIMITED, ENGINEERS, COVENTRY.

Fig. 9.

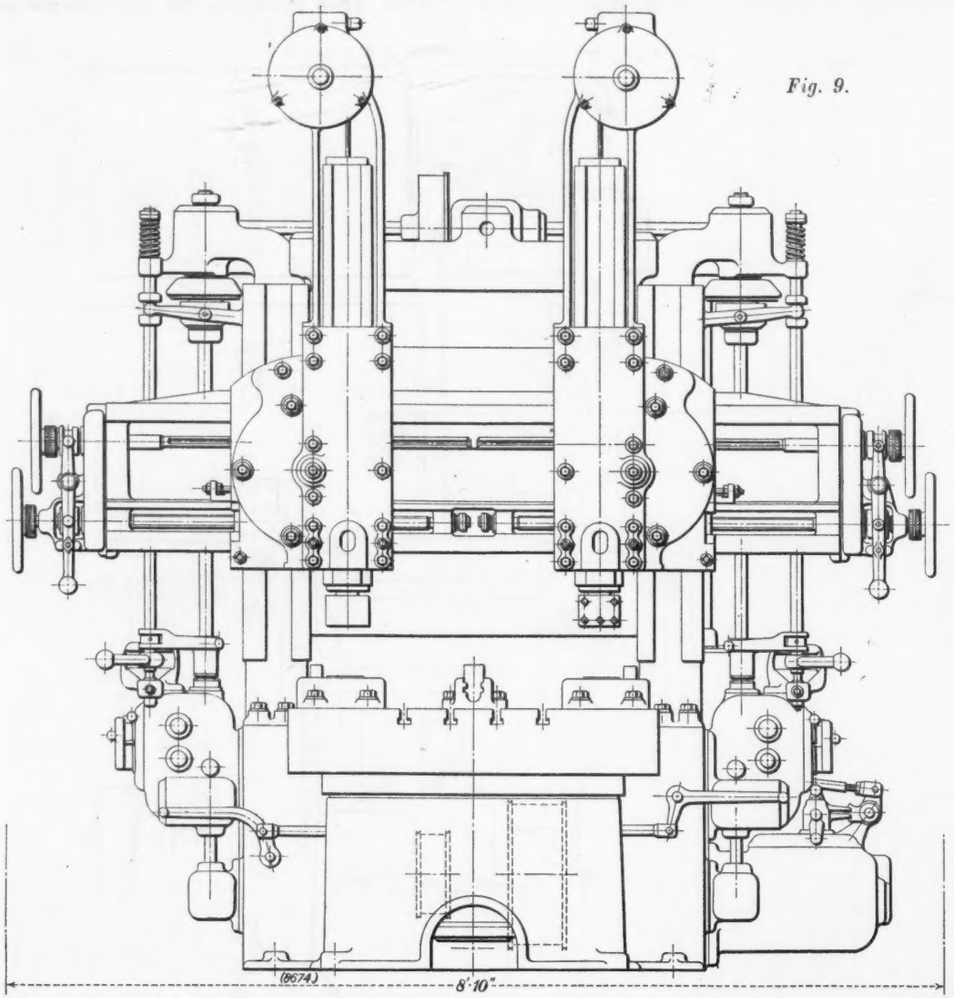
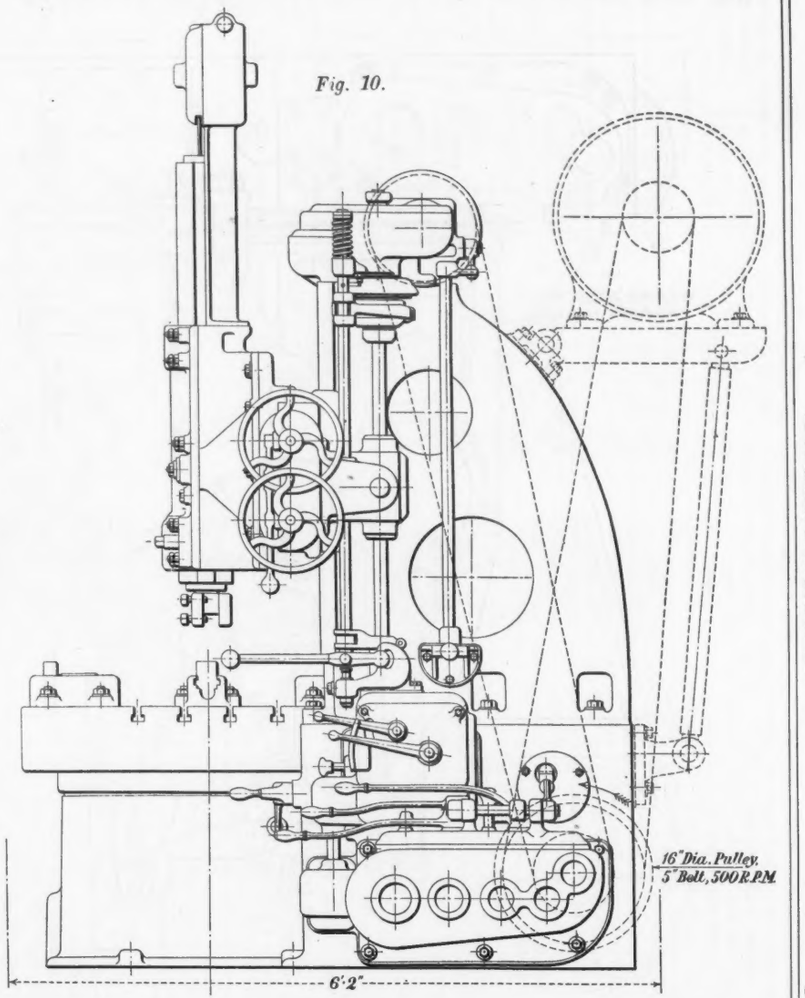


Fig. 10.



own handle or wheel, which need not be removed. All gears are enclosed. Control is centralised as much as possible, while the absence of balance weights gives freedom for crane operations, &c. The guides to slides are narrow, fitted with taper strips. Ball-thrust bearings are fitted to all feed screws and worms.

The double-ram, single 42-in. table, vertical boring and turning mill illustrated in Fig. 6, Plate XXIX, and Figs 9 and 10, above, is another typical machine by Messrs. Webster and Bennett. It departs in several directions from the firm's standard mill, chiefly in having two rams and an elevating cross-slide and the absence of turret heads. Many of the features already referred to in connection with the vertical lathe, and embodied in the standard mills, are naturally to be found also in this machine. The 42-in. table will allow for work 45 in. in diameter, the maximum height under the tool holders being 30 in. and under the cross-slide 34½ in. Under the tool slide 30 in. is admissible. The vertical feed of the rams is 22 in. The machine is driven by a constant-speed belt pulley 16 in. in diameter running at 500 revolutions per minute, taking a belt 5 in. wide. Ten horse-power is recommended. The gear-box gives 12 changes of table speed. The cross-slide is arranged with power-elevating motion. The ram heads swivel and can be set for angular cutting. The 12 rates of feed available are independent for each ram head. Safety clutches are introduced into the feed-gear mechanism. All gears are interlocked. Rapid-power traverse is available for all

100-IN. "HILOMILL" AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. JOHN STIRK AND SONS, LIMITED, ENGINEERS, HALIFAX.

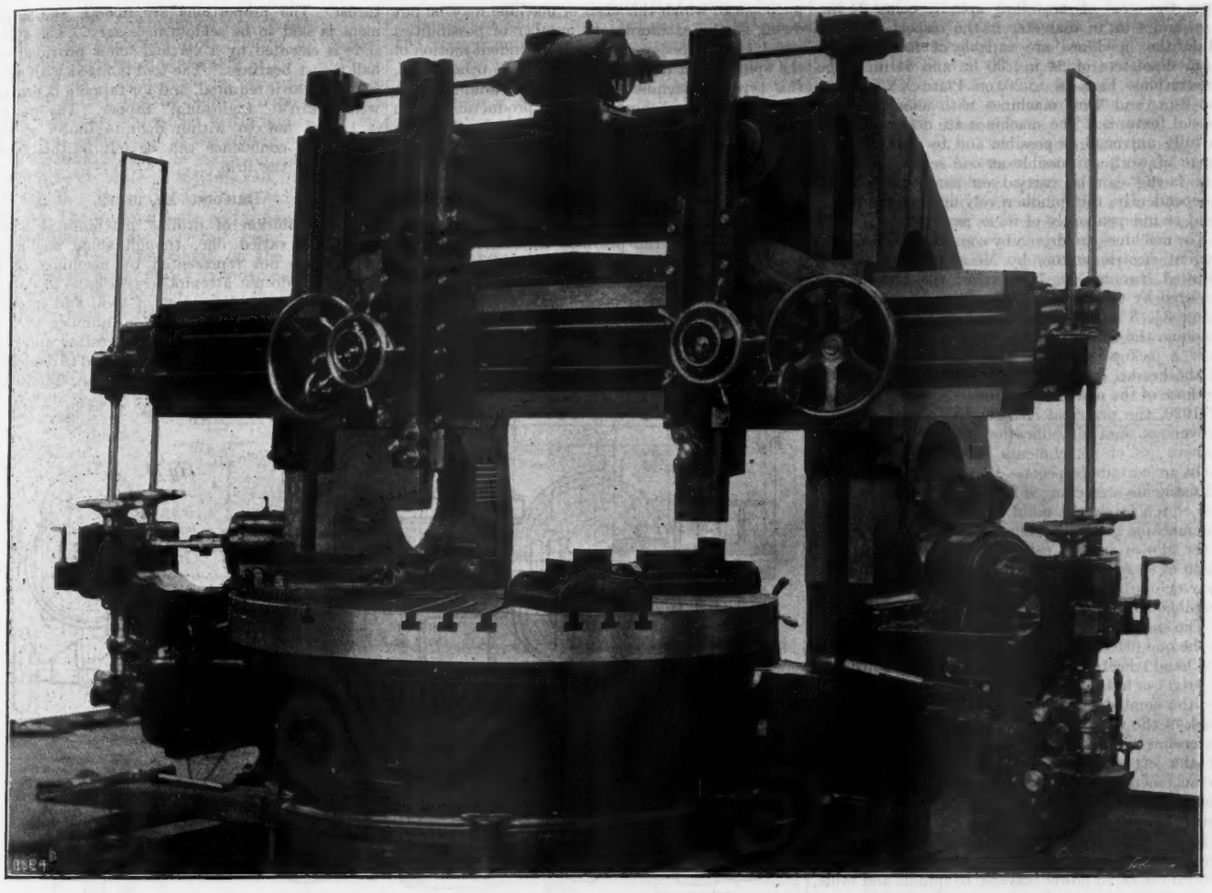


FIG. 11.

motions. A friction clutch is fitted on the first motion shaft of the main gear-box, and is controlled by a lever on each side of the machine. Great attention has been given to lubrication. The large-diameter pressure ring under the chuck is continuously fed with filtered oil, the level being always in view of the operator. With regard to declutching of the driving pulley before speed changing and a large number of other features of design and construction, such as the quality of gears, the use of ball bearings, the balancing of the rams, centralised control, &c., remarks made in connection with the 36-in. vertical lathe apply equally to this machine, which is primarily intended to accommodate work of a greater length than is commonly machined on the firm's standard vertical mills.

Messrs. John Stirk and Sons, Limited, have an exhibit which is probably the most impressive as regards size of machine, to be seen at Olympia. The firm is showing two boring mills and two planing machines with, in addition, a self-contained split field planer conversion set. The firm, it may be remembered, showed the largest planing machine to be seen at the 1920 Exhibition, but have far surpassed that on the present occasion. The boring mills are respectively 100-in. and 48-in. machines. For the moment, owing to the space required by an illustration which would do justice to so large a tool, we must confine our attention to the 100-in. "Hilomill," which is depicted in Fig. 11, above. This particular machine, turning up to 8 ft. 4 in. diameter, has a table diameter of 7 ft. 6 in. The maximum height from table to underside of cross-slide is 58 in., and under tool holders is 48 in. The height of the table from floor level is 2 ft. 9 in. The main motor for driving the table is situated on the left-hand side of the machine. It is a variable-speed machine of 25-h.p. capacity, with 3 to 1 variation. In addition to this there are three changes provided in a gear box, so that the mill has a very wide continuous range of speed suitable for all classes of work. The housings are tongued, keyed and bolted to the body and at the top are connected by a deep cross rail. The vertical guides on the housing faces are 12 in. wide. The cross slide has guides 14 ft. 8 in. in length by 22 in. deep for the tool saddles, while the vertical length of the cross slide on the housing faces is 2 ft. 8 in. The cross slide height is regulated by a motor on the cross rail driving the elevating screws by worm gearing. The table is driven by a large spur directly under the table, and a vertical pinion.

The two rams have a length of 5 ft. 10 in., excluding the tool holders, which are designed for tools $1\frac{5}{8}$ in. square. The rams are spring balanced and arranged on swivelling heads on the saddles. The rams are independent and each head is provided with a separate feed gear box, one on each side of the machine, so that for each head there is a selection from among nine feeds for horizontal, vertical or angular cutting, regardless of the setting of the other. Quick change and reverse are effected by levers on the gear box, and selector clutches operated from floor level engage either the horizontal, vertical or angular feeds.

Hand wheels at floor level provide for fine adjustment when setting in the cut, these adjustments being also duplicated on the heads themselves. For quick-power traverse, Stirk patent motors are fitted, one for each head. Selector switches, operated by levers interlocking with the feeds, enable either motor to be run at will by the same pendant switch. A third selector switch enables the cross-slide elevating motor to be run in either direction from the same pendant switch. The general arrangements, as in all Messrs. Stirk's heavy machines, provide quite remarkable facilities of control.

HORIZONTAL BORING, DRILLING AND TAPPING MACHINES.

The examples of horizontal boring, drilling and tapping machines at this year's Exhibition are not so numerous as on the last occasion of 1920. There are, however, some well-known makes to be seen. Examples by Messrs. H. W. Kearns and Co., Limited, Broadheath, Manchester, embody a number of improvements introduced since we last dealt with this firm's models. The firm is now exhibiting three of their universal surfacing, boring, milling, drilling and tapping machines. This type of machine, as is well known, has been developed to give it possibly a wider range of capabilities than that of any other so-called universal machine. Various methods are employed by different makers in designating these tools, the commonest being probably to give the size of spindle, though this does not actually convey much idea of the kind of job that can be accommodated, which forms so frequently the measure of, for instance, lathes, drills and other machines. On the other hand, size of work alone is little to go by, and it is difficult to find a really satisfactory unit by which to describe these serviceable tools. We cannot pretend that the numbered sizes adopted by some makers convey anything of practical usefulness to the mind, as these must at once be referred

to some other measure before the service of which a machine is capable can be appreciated in the least degree.

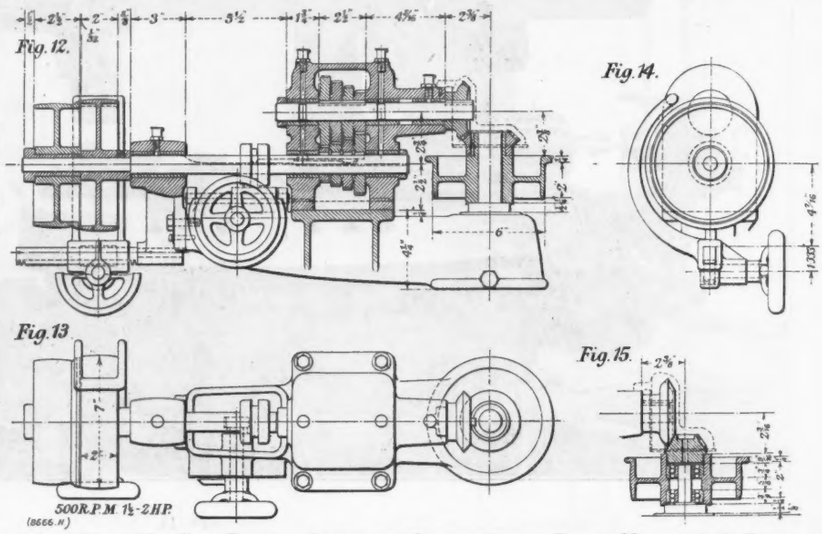
The three machines of this class exhibited by Messrs. H. W. Kearns and Co. designated as their Nos. 1, 2 and 4 sizes, are of the Kearns patent type, the sizes of travelling spindle being 2½ in., 3 in. and 4 in. in diameter in the respective cases, while the machines are capable of facing maximum diameters of 24 in., 30 in. and 54 in. The illustrations, Figs. 16 to 20, on Plate XXX, show the 3-in. and 4-in. machines with some of their special features. The machines are designed to be as fully universal as possible and to do as large a range of work as possible at one setting. Boring and facing can be carried on simultaneously or independently, the spindle revolving with the facing head or independently of it, as required.

The machines are driven by constant-speed direct-current electric motors by Messrs. Electromotors, Limited, running at 750 r.p.m., the horse-power required by the three sizes shown at the exhibition being 3½, 5 and 10 respectively. In the Kearns machine the drive to the spindle is by belt passing over a jockey pulley to allow for the adjustment of the head. In the main the motions are similar to those of the machines exhibited at the Exhibition of 1920, the principal changes having been in improvement and simplification of the control, the elaboration of attachments, and increased refinement in certain respects. Power and quick hand adjustments are arranged for all movements. With the clutch lever, the main gear-box at the back of the machine gives eight changes, obtained by a gate lever shown in the right foreground of Fig. 20. Each of these speeds can be used direct, or in single gear or double gear with a back shaft, making the possible speeds 24 in number.

The starting-clutch lever, controlling two changes, is the one fitted with a handle catch, shown outside the hand wheel in Fig. 20. This is moved either to the right or left. The back shaft gears are controlled by the small hand wheel shown in Fig. 16 at the back of the top part of the head, above the spindle extension casing. The feed gear-box will be seen at the left-hand end of the bed (Fig. 16). This arrangement is much as it was before. The main controls grouped in front of the machine have been much simplified by the further use of gate-change levers. Four levers now replace seven formerly employed. Thus two separate levers which controlled the rapid power traverse to spindle and table, and a lever for releasing the main feed when using the rapid power motion, are combined in one gate lever arrangement operating both the main feed and rapid power motions, automatically locking each as necessary, so that when the feed is operating the rapid traverse cannot be engaged, and *vice versa*. This control lever is the one in Fig. 20, shown fitted with a treadle close to the clutch lever spindle. Further simplification of control is introduced by means of a single gate lever, replacing two levers previously used separately to control the longitudinal and cross traverse of the table, in or out, in conjunction with a third master lever for the table and head motions. One gate lever now operates the vertical movements of the head, and longitudinal and cross-traverse motions of the table for feed and rapid power movements. The adoption of the gate-change levers eliminates all risk of engaging conflicting speeds or feeds.

The spindle slide and boring stay are both fitted with Messrs. Alfred Herbert's metroscope, enabling the travel of moving parts to be measured quickly with accuracy, and greatly facilitating quick setting. The illustrations in Figs. 17 and 18 show the arrangement adopted when the machine is required for gear cutting or hobbing. Spur and worm gears up to 60 in. in diameter can be machined by a cutter mounted on the face plate, which is locked during this operation. The reduction gear drive from a bevel mounted on the spindle nose is well shown in Fig. 18. A special circular, revolving, indexed table is used for this work, arranged for hand and power feed. Another application of the machine is shown in Fig. 19, which illustrates a grinding attachment. In this the grinding wheel is carried by a spindle geared up from the main spindle, the attachment being mounted on the face plate, which may be fixed or may also be revolved at the same time. This arrangement allows of a large range of internal and external grinding work, while work may also be bored and ground at one setting. As will be seen, these attachments are self contained. They can be fitted up in a few minutes. These and other arrangements are examples of the large variety of purposes to which this class of machine may be put owing to the extraordinary number of possibilities which exist on account of the independent motion of the spindle and facing chuck. On the other hand, this type of machine has often been adopted as a single-purpose machine on mass production, when the arrangements of the controls and quick power traverses greatly facilitate maximum output.

Another machine of this class is the "Pearn-Richards" facing, boring, milling, drilling and tapping machine. We have given illustrations of this machine on former occasions, notably in connection with the previous Exhibition of 1920 (see vol. cx, page 306), but this line of tools made by Messrs. Geo. Richards and Co., Limited, Broadheath, Manchester, is of a standing to warrant a further reference to it in connection with the present Exhibition. The size shown is the firm's No. 2 machine which is being made in six sizes in all, ranging from a machine capable of facing and edging circles up to 18 in. in diameter, to the largest size which can face and edge circles up to 72 in. in diameter. The No. 2 size shown deals with work up to 24 in. in diameter. The head is capable of vertical adjustment from 4 in. up to 23 in. above the revolving table, or 8 in. to 27 in. above the sliding table. The facing tool slide feeds on the facing head are for roughing, moving inwards 25 per inch, and for finishing, which is done on the outward cut, 12 per inch. The feeds, longitudinally and transversely to the table, and vertically to the tool slide, are eight in number, ranging between 100 r.p.m. and 8 r.p.m. of spindle to 1 in. of travel, all being instantly changeable and reversible. A safety clutch prevents damage to the feed gears. The spindle speeds are 32 in number, ranging from 3·8 r.p.m. to 200 r.p.m. The bed has a length sufficient to give 5 ft. 5 in. clear between the boring bar socket and the stay, while the sliding work table has a surface of 48 in. by 30 in. and a longitudinal traverse of 42 in., with 32 in. cross movement. All feeds are automatic, and quick-power traverses are provided. By means of snout boring and facing tools the range of work on these machines can be very greatly increased, and a large series of surfaces can be machined at one setting instead of the work even requiring to be turned on the table. Above the sliding table is fitted a square revolving table 30 in. by 30 in. which can be quickly clamped in any position. This table revolves on a centre pin which, by means of a small lever in front of the slide, can be raised slightly so as to lift the load off the sliding table below, in order to facilitate accurate adjustment. The spindle is carried in one parallel and one taper bearing, the former being 2⅜ in. diameter, and the latter 6½ in. long and varying from 3¾ in. to 4⅞ in. with a short taper neck at an angle of 45 deg. to resist severe end thrust. The proportions are liberal, and adjustment is said to be seldom necessary. The spindle slide is elevated by a vertical screw provided with ball thrust bearings. The tool is fitted with screw-cutting gear if required, and for tapping is provided with Pearn's "Lightning" tapper. The machine is turned out to within definite limits of error and every confidence can be felt in this typical product of the firm.



FIGS. 12 TO 15. GEAR-BOX AND DRIVE FOR GEARED RADIAL DRILL; MESSRS. A. A. JONES AND SHIPMAN, LIMITED.

DRILLING MACHINES.

The exhibition of drilling machines is a very large and varied one, though some well-known makers are not represented by machines of this type. We do not attempt in this issue to do more than touch upon this class of tool, and intend in future articles to deal with a number of other examples, all in their way as interesting and representative as those we shall now proceed to describe.

Messrs. A. A. Jones and Shipman, Limited, of Leicester, are exhibiting a number of grinding machines as well as a variety of drilling machines. The former we deal with in another section of this article; the latter include a number of designs which have been among the makers' standards for some little while, such as a 20-in. heavy-duty drill with back gear and tapping reverse, a 10-in. multiple three-spindle ball-bearing sensitive drill, a 14-in. high-speed sensitive, a 12-in. precision ball-bearing drill on column, and ¼-in. tapping machine. In addition to these a number of quite new machines are shown, including a 25-in. nine-speed all-geared drilling machine, a 20-in. all-geared three-spindle drill, a 3-ft. all-geared sensitive radial, a 16-in. three-spindle extra-power sensitive, and a 12-in. jeweller's bench drill.

The firm's 36-in. sensitive geared radial drilling machine is illustrated in Figs. 12 to 15 above and Figs. 21 to 24, Plate XXXI. It is a development of a former belt-driven pattern. The gear box and driving pulleys are mounted on an arm which can be swung to any suitable position on the column to receive the belt drive. The arm and gear box shown in detail in Figs. 12 to 15, on this page. In Figs. 22 and 33 they are partly hidden, being fixed at right angles to the table and base. With the driving pulley running at 500 r.p.m. the gear box for the machine when fitted with ball bearings gives four changes of 508, 680, 982, and 1,418 r.p.m. for the spindle. With gunmetal bearings only, the speeds are 273, 378, 546 and 788 r.p.m. The spindle diameter is 1 in. in the quill, and the quill diameter 1⅝ in. The maximum distance from the nose to

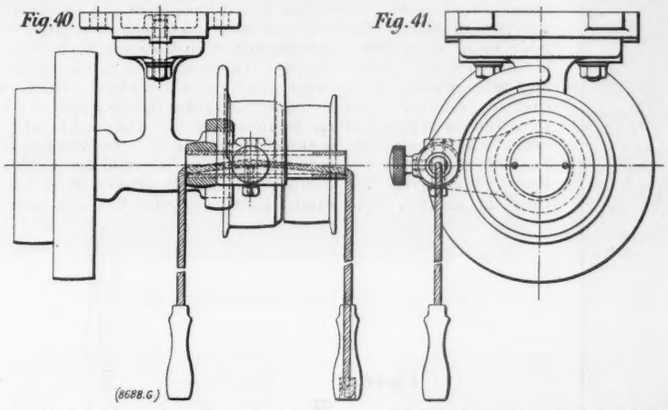
the table is 28 in. and the minimum, 6½ in. The head can be moved over a range of 32 in. for the 36 in. radial arm. The feed of the quill is 5 in., and the vertical adjustment of the table 16½ in. The table for the 36-in. drill is 21 in. by 35 in. On one side it has a vertical face 6½-in. deep with two tee slots. The belt driving the head is 1½ in. wide. Fig. 24 shows the pulley arrangement for this belt.

The 25-in. all-geared drill, shown by Messrs. Jones and Shipman, is illustrated in Figs. 25 to 27, Plate XXXI. This machine will drill up to 2-in. holes. It is heavily built and provided with a stiff back-stay. The feed to the quill is 12 in., the vertical adjustment of the sliding head 14½ in. and of the table 21½ in. The maximum distance from spindle nose to table is 36½ in., and from nose to base 49¾ in. From the spindle centre to column is 12⅝ in. The working surface of the table is 17 in. in diameter, the table, overall, being 21½ in. in diameter. The countershaft on the base has a 12-in. constant speed pulley provided with a friction clutch worked by a handle close to the spindle head. The pulley runs at 350 r.p.m., at which speed the nine-speed gear box at the top of the machine gives spindle speeds ranging between 34 to 437 r.p.m. These changes are obtained with sliding steel gears operated by two broad-rimmed hand wheels on the right side of the head. The rims are lettered and a plate on the column indicates the combinations of letters for the different speeds obtainable. The gears are completely enclosed and foolproof. The quill is ground and graduated. An automatic adjustable stop is provided and quick hand feed and return is arranged for. The automatic feed and fine hand feed are through a worm gearing. A clutch handle at the head provides instant release for the feed. Four feeds are available ranging from $\frac{1}{53}$ in. to $\frac{1}{179}$ in. per revolution. These changes are obtained by means of a handwheel on the right side of the head close to the front of the machine. The table can be rotated on its centre and the whole swung round the column. It is raised and lowered by worm gear rack and pinion. The spindle has a diameter of 1⅝ in., and is drilled to No. 4 Morse taper. The quill diameter is 2¾ in. The drill takes from 3½ to 4 h.p. The spindle and sliding head are separately counterbalanced by weights in the main column.

Figs. 28 to 30 illustrate the multiple spindle all-geared type of drill. The drawings show a two-spindle machine; the photograph reproduced is of a three-spindle machine. The heads are standard, the machines varying only as regards base and countershaft. This type of tool has been specially designed for mass production work. The functions of the various control levers, &c., are indicated in Figs. 29 and 30. The drive to the head is from a constant-speed countershaft running at 400 r.p.m. The gear box on the head gives four speed changes controlled by a hand wheel, all of which can be used direct or in combination with back gear, giving eight changes, ranging from 30 to 382 r.p.m. The gears are of hardened steel and run in an oil bath.

The spindle diameter in the quill is 1⅞ in., and it is bored to No. 3 Morse taper. The quill diameter is 2½ in. Three feeds are given by a lever on the head, viz., 60, 120 and 240 r.p.m. The maximum feed of the quill is 10½ in. and the adjustment of the sliding head 8 in., that of the table being 18 in. The maximum distance from spindle nose to table is 28 in. The table is fitted with a telescopic elevating screw. The spindle and feed mechanism is composed of 20-in. "New Century" drilling machine components. The spindle and sliding head are counterbalanced by a single weight inside the column for each drill. The tapping reverse mechanism is operated by a hand lever with positive locations for the start, stop and reverse positions of a central clutch, which slides on a sleeve between the clutches for the spindle. Figs. 29 and 30 show both heads fitted with tapping reverse gear; Fig. 28 shows only one of the three heads so fitted. The two-spindle machine has a working surface for the table measuring 13 in. by 34 in.; for the three-spindle machine the table is 13 in. by 42 in., and for the four-spindle pattern 13 in. by 54-in. For the three machines the horse-power required is about 4, 5 and 6. We hope to refer in a later issue to other exhibits of Messrs. A. A. Jones and Shipman, Limited.

The exhibit of Messrs. Frederick Pollard and Co., Limited, of the Corona Works, Leicester, is a very extensive one, including nearly 40 models of drilling machines of the firm's manufacture, in addition to a few other machines of different classes, for which they act as agents. No less than 19 of the drilling machines are shown in motion, so that the display is most instructive and attractive. The three classes of high-speed sensitive, upright and radials are well represented. In the high-speed ball-bearing class, with spindles designed for speeds up to 10,000 r.p.m., ranges of models are shown from bench and single column patterns to multiple-spindle machines with four spindles. These precision drills are among some of the most interesting of the new models shown. Three of one pattern of 12 in. are to be seen, and two of these we illustrate in Figs. 31 to 39, Plate XXXII, and Figs. 40 and 41 annexed. The models only differ in the multiple arrangement and in the base. The general drawings, Figs 31 and 32, represent a four-spindle multiple. A single-spindle machine has the same type of column head, the single head being mounted on a single-column base. In side elevation the single-spindle machine is almost exactly as shown in Fig. 32. In the bench-type machine, shown in Fig. 33, the same type of column head is mounted directly on a bench table and by this selection of illustrations we are able to show practically the three models as exhibited. These drills are belt-driven and have six spindle speeds. With a supplementary countershaft speed of 1,200 r.p.m., the spindle speeds are 1,440, 2,400, 3,360, 4,320, 7,200 and 10,080 r.p.m. The vertical movement of the spindle is 3 in., and of the bracket 6 in., while the table is adjustable through a range of 22 in. The maximum distance between the end of the chuck and the work-table in the case of the column drills is 2 ft. 7 in. The size of the work-table varies from 12 in. by 10 in. in the single-spindle pattern to 33 in. by 10 in. for the four-spindle multiple. The bench pattern, of course, differs from the foregoing. In this case the spindle movement is only 3 in., while the bracket adjustment is 5½ in. The maximum distance from chuck nose to table is 11 in. The size of the table is 12 in. by 12 in. The details of the head, which are virtually the same for all the machines, are shown in Figs. 34 to 37, Plate XXXII. The chief features are the mounting of the ball-bearing spindle and the flat belt drive. The spindle is of hard carbon steel and as small in diameter as the requisite strength allows, to secure lightness. In order to increase this the spindle is hollowed out at the upper end. The spindle ball-bearings run immersed in oil, grease not being found satisfactory for continuous work at the high speeds used. With the exception of the end, the whole spindle is covered, telescopic guards allowing for any movement of the sliding bracket. The guards not only make the drills safe, but keep all dirt from the bearings. The quill is cut with teeth from the solid. With the exception of the thrust and journal housings the bore is clear of the spindle. The quill has a keyway and feather to prevent rotation in the bracket, as shown in Fig. 35. At the bottom of the quill the spindle is carried in a ball bearing and, in addition, a thrust bearing is provided, the two being separated from each other. The cover is made in the form of a cup, the side of which extends up the bearing housing to form the oil bath. In the centre the spindle is fitted with a cup and cone ball bearing, to eliminate friction between the adjusting nut and quill and prevent whip in the spindle due to its light section. The upper bearing is quite novel in design, the inner bush being fixed to the pulley and revolving with it. The arrangement makes the introduction of an oil-bath possible and gives increased support to the spindle. The inner bush consists of a long hollow spindle on which the ball races and driving pulley are all locked together. The keys driving the spindle pass through the bush from the pulley keyway to keyways in the spindle. The spindle



FIGS. 40 AND 41. SUPPLEMENTARY COUNTERSHAFT FOR PRECISION BENCH DRILL; MESSRS. FREDERICK POLLARD AND CO., LIMITED.

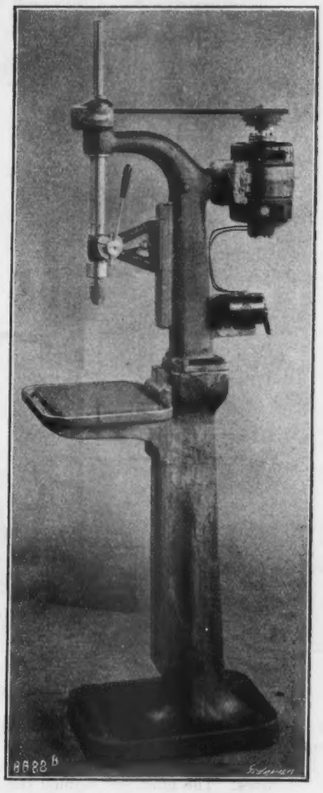
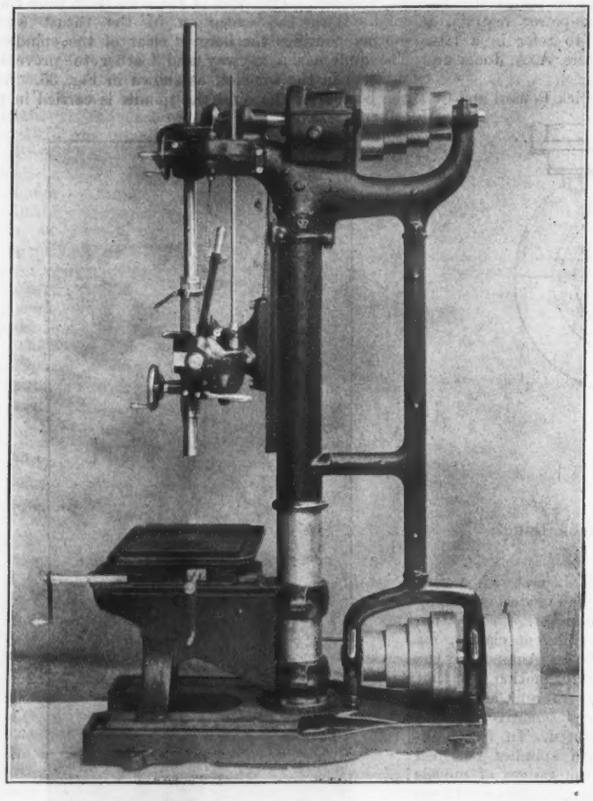


FIG. 42. MOTOR-DRIVEN BALL-BEARING SENSITIVE DRILL; MESSRS. FREDERICK POLLARD AND CO., LIMITED.

pulley is of aluminium to reduce its weight. Guards are fitted in front of it and on the spindle end.

The feed is by lever through the cross axle as shown in Figs. 35 and 36. The lever can be adjusted to any length and is then held by a spring in the cross axle end. The spindle balance is taken by a flat coil spring (Fig. 35), the tension of which is adjustable to extreme sensitiveness. The cross axle is fitted with an adjustable depth stop shown in Fig. 36. This consists of a pin projecting from an adjustable eccentric. The latter can be clamped in any position so that the pin comes in contact with a lug on the spindle bracket at the desired depth. The pin can be withdrawn if greater movement should be required, without disturbance of the stop. The bracket head when adjusted is clamped by a bolt and locking handle. The drive is illustrated in plan in Fig. 37. Ball-bearing pulleys are provided set to correct angles to give the best belt track.



The bracket carrying the pulleys is adjustable to secure proper belt-tension.

Fig. 38 illustrates the countershaft for the single spindle machines. The multiples employ the same type but with more pulleys and have an additional supporting ball bearing. The shaft is provided with standard ball bearings with retaining collar and dust caps. The speed being lower than in the case of the spindle, grease lubrication is found satisfactory, the lubricant being injected by means of a grease gun. The drive is through metal to metal cone clutch, the female part running on ball bearings when free. The lever operating the clutch from the front of the machine has a spring plunger falling into a hole when the clutch is withdrawn. The cones are closed together on starting by means of a coil spring. On either side the countershaft bracket can be quickly removed so that endless belts can be readily put on. The cone pulley slides on the shaft, being driven by a feather let into the shaft. The belt positions are correctly located by an internal spring plunger, as shown in Fig. 38. The supplementary countershaft at the base of the machine is illustrated in Fig. 39. This is also mounted on ball bearings. The two-step pulley on this shaft considerably extends the range of speeds obtained with the main countershaft. Fast and loose pulleys and the requisite belt striker are provided. This gear is only utilised when the drill is not in use, as in the ordinary way during work the clutch on the countershaft provides for all stopping and starting. The supplementary countershaft is adjustable for belt tension. In the case of the bench type drills the supplementary countershaft takes the form shown in Figs. 40 and 41, page 315. This can be fitted as convenient, the belt striker revolving on the bracket and being capable of being fixed to serve the belt from any direction. The belt striker is worked by flexible cord from ground level. The bracket is mounted on a slide which allows of adjustment for belt tension.

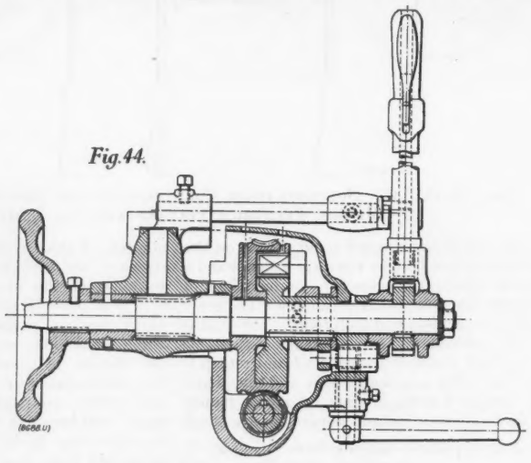
Fig. 42, page 315, represents a new motor-driven ball-bearing, sensitive drilling machine also shown by Messrs. Frederick Pollard and Co., Limited. This little machine is made in several types, embracing column designs and a bench pattern. The arrangements are very similar in all, though the capacities vary to some extent. The work-tables on some of the column types are balanced. In the pattern shown the table works on a slide; in others a circular swivelling table works on a circular column, and these can be supplied to cant to any angle from the horizontal to the vertical. The speeds are three in number, from 1,900 to 6,000 revolutions per minute. The spindle bearings are totally enclosed and run in oil baths. Telescopic guards are provided. The size is 12 in., and the capacities for three of the types are $\frac{1}{16}$ in., $\frac{1}{2}$ in., and $\frac{3}{4}$ in.

The 24-in. upright "Corona" drill of Messrs. Frederick Pollard, shown in Fig. 43, is fitted with a self-contained compound table, which is rather uncommon for drills of this type; the usual pattern of 22-in., 24-in., and 27-in. upright drills of this class have the ordinary circular revolving table. The main features of this design of drill embrace enclosed back gears, balanced sliding head, and instantaneous friction feed. The latter is fitted to the cross-axle on the head, and is illustrated in Fig. 44, above. The right-hand bottom handle in this figure operates a plunger in the sliding-head casing. On the inner end of the plunger is a roller working in a groove on a sleeve on the cross-axle. One end of this sleeve is tapered, and against this conical portion rests an adjustable stop on a curved arm pivoted in the clutch body. The pivot of this arm has two flats, on either side of which are the internal-clutch segments. When the sleeve is forced in, the tapered surface presses the bent arm out, and the twist given to the pivot forces the segments apart and into contact with the female portion of the clutch, which otherwise revolves freely on the cross-axle.

Messrs. Frederick Pollard's all-geared radial drills are illustrated in Figs. 45 to 48, page 317. These machines have been improved in several ways since they were shown at the 1920 Exhibition. They are made in 36-in. and 48-in. sizes. The machines have constant-speed belt drive, with change-gear mechanism giving nine spindle speeds. The arm is fitted with a ball-thrust bearing to carry the load and ball-journal bearings at the upper end. The driving bevels at the top of the column are also fitted with ball-thrust bearings. The saddle is arranged to run on rollers, and the spindle is fitted with instantaneous friction feed.

A view of the feed mechanism with covers removed is given in Fig. 46. The saddle is a single casting and is carried, as stated above, by rollers; these run directly on the radial arm. The quill is graduated, has rack teeth cut from the solid, and is lined with phosphor-bronze. Four rates of speed, of 54, 81, 121 and 185 revolutions per inch, are obtainable, with sliding gears operated by a single lever. The automatic feed is by expanding friction clutch contained in the worm wheel run off a worm on the feed driving shaft. A detail of the cross-axle and friction-feed clutch is given in Figs. 47 and 48, and is on lines similar to that shown in Fig. 44. The description of the latter will serve to make the mechanism clear. An automatic stop to the feed is carried on the quill and acts directly on the friction clutch. The hand feed by star wheel is also shown in Fig. 47. The whole of the vertical gears and feed worm wheel are totally enclosed. Further reference to Messrs. Frederick Pollard's exhibit must be deferred to a subsequent issue.

Fig. 44.



FIGS. 43 AND 44. 24-IN. UPRIGHT "CORONA" DRILL; MESSRS. FREDERICK POLLARD AND CO., LIMITED.

The 6-ft. 6-in. radial drill, illustrated in Fig. 49 and shown at the Exhibition, is a development of a type introduced by Messrs. Alfred Herbert, Ltd., Coventry, just four years ago. The design embodies many valuable features, due primarily to the mounting of the motor on a back extension of the radial arm. The drill is only built for direct electric driving and as all moving parts are on the arm all risk of danger from belts, pulleys, gears and spindles at floor level and upwards, is eliminated. The only running shaft, except those in the saddle, is the main shaft from the motor passing at the back of the column to the saddle. This can be engaged by clutches to rotate a nut on the elevating screw, for raising or lowering the arm, or can be clutched in to drive the main spindle through the saddle gearing. The abolition of vertical rotating shafts and gears results in a very neat and quiet-running machine. The weight of the motor tends to balance that of the radial arm. The circular column is surrounded by a long sleeve, provided at the top with a ball bearing and at the bottom with a roller bearing. The saddle is supported on the arm by rollers. These fittings make the setting of the drill very easy, the effort required to affect movement being very slight. The radial arm is circular in

DRILLING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

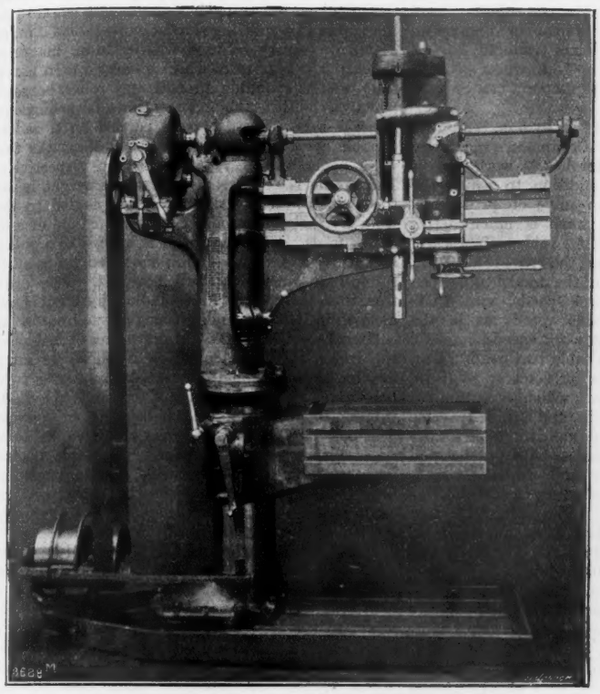


FIG. 45. GEARED RADIAL DRILL.

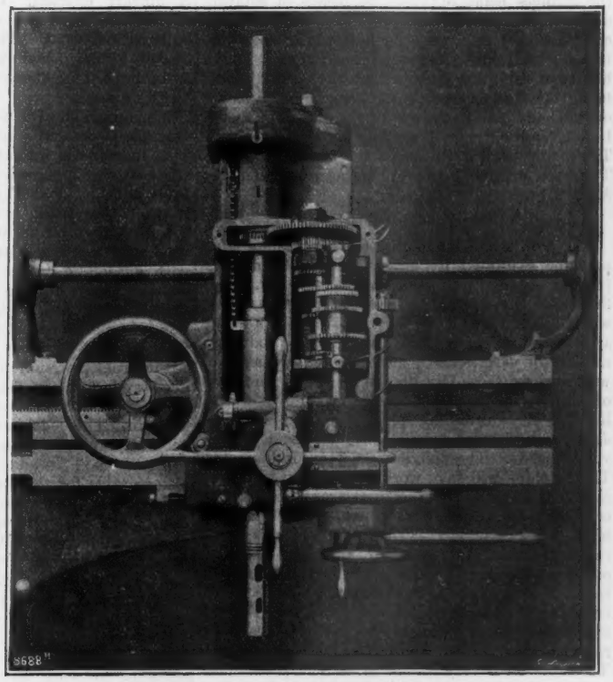
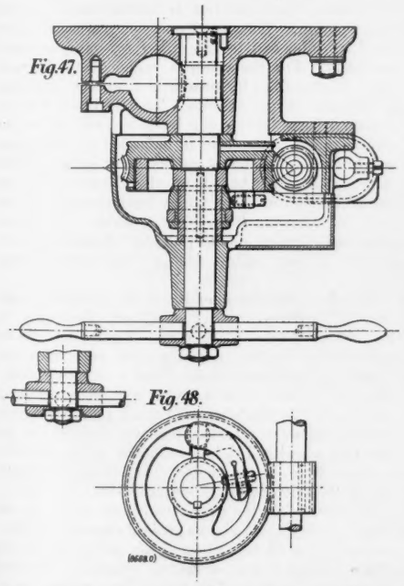


FIG. 46. SADDLE OF GEARED RADIAL DRILL WITH COVERS REMOVED.



FIGS. 45 TO 48. 3-FOOT GEARED RADIAL DRILL; MESSRS. FREDERICK POLLARD AND CO., LIMITED.

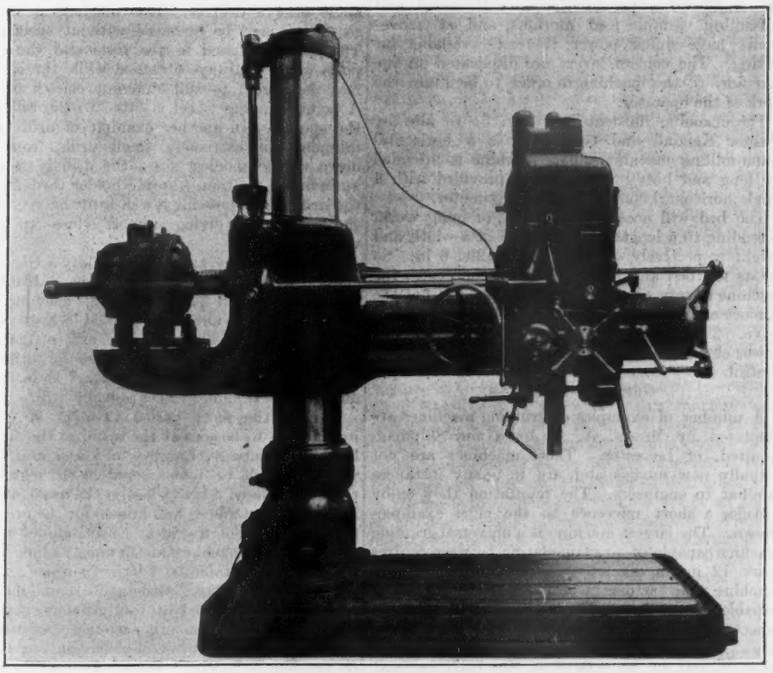


FIG. 49. 6-FT. 6-IN. RADIAL DRILLING MACHINE; MESSRS. ALFRED HERBERT, LIMITED.

section. The elevating motion and clamping of the arm are controlled by one lever on the saddle, by which the arm can be unclamped, the elevating clutches thrown in and disengaged, and the arm reclamped, in succession, eliminating risk of engaging the motion while the arm is fixed. Limit stops are provided at the top and bottom of the arm travel.

The saddle is also clamped to the arm by the lever which clamps the sleeve to the column. The saddle is clamped directly behind the spindle by a wedge plunger and screw coupled to the hand lever by a connecting rod. The clamping of the sleeve to the column is by a bolt and eccentric at the bottom of the sleeve, connected to the hand lever through bevels and a horizontal shaft. The fulcrum of the hand lever is not fixed, but floats so that the effort applied to the saddle and sleeve clamps is equalised.

The machine has a maximum height from spindle to base plate of 6 ft. and minimum distance of 12 in. The traverse of the arm on the column is 3 ft. 6 in., and of the saddle on the arm 4 ft. 4 in. The spindle, which has a minimum diameter of 2½ in., has a vertical feed of 18 in. The minimum distance from spindle to column is 17 in. The number of spindle speeds is 16, ranging from 24 to 490 r.p.m. Eight of these are obtained by sliding gears in the saddle, and these are doubled by back gears, operated by friction clutches. The sliding gears are of chrome-nickel steel; they run in an oil bath. All speed

changes are obtained by levers on the front of the saddle; the motor is also started, stopped and reversed by a lever on the saddle. The feeds are six in number, ranging from 28 to 126 cuts per inch, the changes being obtained by means of rotating dials on the saddle front. The feed gears are chrome-nickel steel and the feed worm phosphor-bronze. Automatic feed stops are arranged. Oiling has been carefully attended to, the oiling places being few and conspicuous. Two large oil boxes on the saddle and arm ensure the necessary distribution and only need refilling at long intervals. The motor fitted to the machine is of 8 horse-power. The base provides a working surface, 6 ft. 1 in. by 3 ft. 8 in.

PLANO-MILLING MACHINES.

Fig. 50, Plate XXXIII, illustrates a plano-milling machine exhibited by Messrs. Kendall and Gent (1920), Limited, of Gorton, Manchester. This firm were the originators of this type of machine, which has acquired a position quite its own in heavy and gang milling work. The makers produce a number of variations to meet the requirements of works where there is a preponderance of one class of work or another. The large machine exhibited has two vertical milling spindles on the cross slide, and one horizontal spindle head on the left-hand vertical slide. The spindles are 3½ in. in diameter. The machine will take work 10 ft. long, while the clearance between the columns and under the cross-slide allows jobs 4 ft. 6 in. wide and 3 ft. 6 in. high to be machined. The main drive is by a constant-speed electric motor and gear-box with oil-immersed gears. From this box the drive is taken for all motions, including the spindle drive, cross-slide elevation and saddle traverse. For the spindles, eighteen changes of speed are available, ranging from 11 to 166 revolutions per minute. The table feeds vary from 1 in. to 8 in. per minute, a choice of nine changes being available, independent of the spindle speeds. All changes are by lever, without stopping the machine, and only the gears actually transmitting power are in mesh at a time. The saddles are provided both with hand and self-acting variable feed motions, and all movements have quick power traverse available for setting. The control levers are duplicated on the two sides of the machine in order to facilitate the work of the operator.

The machine illustrated in Fig. 51 is also by Messrs. Kendall and Gent, but is a horizontal plano-milling machine. This machine is intended for long and heavy work and is provided with a single horizontal spindle 4½ in. in diameter.

The bed will accommodate jobs, or gang work, extending to a length of 14 ft., and of a width and height respectively of 4ft. 6 in. by 2ft. 6 in. So far as the bed and table drives are concerned, the machine is very similar to the previous one, but the absence of the vertical spindles simplifies the spindle drive. The cross slide is counterbalanced and power elevating motion is provided as well as hand control.

GRINDING MACHINES.

A number of examples of grinding machines are exhibited by Messrs. A. A. Jones and Shipman, Limited, of Leicester. These machines are not actually new models and are in many instances familiar to engineers. The reputation they enjoy justifies a short reference to the chief examples shown. The largest machine is a universal grinding machine capable of accommodating between centres work 12 in. in diameter and 24 in. long. This machine uses a disc wheel 10 in. in diameter capable of running at three different speeds, the wheel having 6½ in. of cross traverse from or to the work. The cross feed is automatic and ranges from 0·0002 in. to 0·0016 in. for each reversal. An adjustable knockout is provided, preventing further cross feeding as soon as the required diameter is reached. The number of table traverse speeds is eight, varying from 15 in. to 109 in. per minute. The table swivels on a spigot and can be set for taper turning up to an angle of 38 degrees from the line of the slide. The headstock also swivels and has a graduated base. It is provided with a two-speed pulley and can carry a faceplate or chuck. The height of the centres is 6½ in. and the working surface of the table is 43½ in. by 6 in. wide. The wheel head is carried on a cross slide which swivels through the complete circle, so that the change from the external wheel on one end of the slide to the spindle for internal grinding is quickly effected. The internal spindles used are of Messrs. Jones and Shipman's high-speed ball-bearing type. Three sizes running up to 40,000 r.p.m., which with a ½-in. wheel gives a surface speed of about 5,000 ft. p.m., can be used on this machine.

A plain grinder for work 24 in. by 6 in. is another example of Messrs. Jones and Shipman's machines. This machine is intended for heavy work and is substantially designed, in addition to which the table slide is inclined at an angle of 35 degrees, so that the thrust of the work is much better taken up than on an horizontal table. The wheel used is 12 in. in diameter and the cross-feed 6½ in., with automatic feeds as in the model described above. There are two wheel speeds, viz., 1,600 and 2,285 r.p.m., eight table speeds as in the previous machine, and eight work speeds, namely, from 72 to 276 r.p.m. The table traverse is 24 in. An internal precision grinder for holes up to 10 in. deep and 8 in. in diameter, which is exhibited, has a swing over table of 12 in. and a table traverse of 18 in. This machine is specially intended for the accurate rapid finishing of holes, both parallel and taper, from ¼ in. diameter and upwards. It is also suitable for the form grinding of such objects as races for ball bearings. The table has four speeds, the work four speeds and the spindle three, ranging from 5,000 to 50,000 r.p.m. The automatic cross-feed is variable from 0·0001 in. to 0·0005 in. per reversal. The work head pulley is fitted with a clutch and brake, the spindle being instantly stopped when the clutch is disengaged by a short lever.

A universal tool and cutter grinder having a capacity for work 18 in. long by 8 in. in diameter and taking an 8-in. wheel running at a speed of 2,545 r.p.m. is also exhibited, as well as two twist drill grinders. One of the latter is for drills from ¼ in. to 2½ in. diameter, giving a fixed cutting angle of 118 degrees. This machine is designed so that it can be operated without special skill. The drill is carried in vee rests and the correct point angle is always obtained while the clearance may be varied to suit different classes of work. A point thinning wheel is fitted to the tail end of the spindle. In another example of drill grinder, intended for extremely small drills from ¼ in. down to the smallest sizes, the drill is ground in an inverted position, a spring holder through which the drill passes pressing it well into the vee block of the carrier and giving support close up to the wheel face.

Messrs. Crossley and Co., St. Mary's Gate, Manchester, among other exhibits, show a Hunt twist drill grinder and point thinning machine. This machine we have already described in ENGINEERING (see vol. cx, p. 399, and vol. cxi, p. 724). The model shown is for toolroom use for drills from ¼ in. to 2 in., using a grinding wheel 14 in. by 2 in. and a point thinning wheel 5 in. by ¼ in.

One of the most varied exhibits of grinding machines is to be seen at the stand of the Lumsden Machine Company, Limited, of Gateshead, a firm which, it will be remembered with regret, has recently suffered a heavy loss in the death of Mr. T. Lumsden, who was so well known for the originality and soundness of the ideas he introduced into his designs. The machines at Olympia include vertical spindle rotary table and other surface grinders, horizontal grinders, planetary head machines, oscillating and curved lip tool grinders, gauge and form tool grinders, and other models. Some of these have formed the subject of notice in our columns on previous occasions. For instance, at the time of the 1920 Exhibition, we illustrated the gauge and form tool grinders, while in vol. cxii of ENGINEERING (pp. 183 and 213 *et seq.*), we devoted a couple of articles to the Lumsden tool system and described the oscillating and curved lip tool grinders. We now propose to notice three machines at the present Exhibition, reserving other interesting tools for a subsequent article. We shall commence with the two machines, illustrated in Figs. 52 and 53, Plate XXXIV, which are of somewhat similar character, but while the one represented in Fig. 52 is intended for a general purpose tool, that illustrated in Fig. 53 is a simplified machine of more limited range, and is intended primarily to be used more as a single purpose tool. Dealing with the general purpose machine first, the actual one illustrated has a segmental wheel 18 in. in diam. and a rotating slotted work-table 36 in. in diam., or it may be used with a 36-in. magnetic chuck. The segmental wheel is carried on a heavy steel spindle running in ball and roller bearings and a special thrust arrangement, in a large diameter vertical ram. The latter is carried in a saddle capable of movement on a vertical slide, the two ways being of the V and flat type respectively. The saddle is counterbalanced by a weight inside the column. The grinding wheel is fed to the work by the ram, which has a wide range of self-acting feeds. The main drive is by belt to a pulley at the head of the column, mounted on a shaft running in dust-proof ball bearings. The drive from this shaft to the wheel spindle is by spiral bevels inclosed in the rectangular casing at the front of the column head. This type of drive greatly enhances the range of the machine, as it allows of much heavier transmission than the short quarter twist belt drive. The table drive is transmitted by belt, running on three step-cone pulleys, to an epicyclic gear-box close to floor level, the possible table speeds being six in number. The table control lever is close to the table, while a lever dependent from the head controls the wheel drive clutch. The feed drive is by belt from the spindle to a shaft on a small gear-box on the side of the saddle.

In the machine shown in Fig. 53, a 24-in. wheel is used and a 48-in. table or magnetic chuck. The maximum height under the wheel is 12 in. or, if a magnetic chuck is used, 6 in. The main drive is again to the top of the column, where there is a 15 in. by 9 in. pulley running at 700 revolutions per minute on a shaft driving the spindle through spiral bevels. The machine takes from 25 h.p. to 30 h.p. The spindle is carried in a large ram in a cylindrical housing, which is not capable of vertical adjustment as in the case of the saddle of the former machine, but is bolted direct to the back column. The ram has a vertical adjustment of 12 in., and can be fed either by hand or automatically. For the latter, a range of 10 different rates is available, by means of a change gear-box at the side of the column. The feed-box drive is obtained from the spindle by belt drive above the column head. The ram is balanced by two large weights hung on chains carried over pulleys. The table drive is by belt from the mainshaft at the top of the column to a pulley near the floor at the back of the machine. Three table speeds are possible by means of cone pulleys. A friction clutch in the bottom pulley engages the table driving gear.

The third notable machine is the planetary-head type of surface-grinding machine illustrated in Fig. 54 on Plate XXXIV and Figs. 55 to 58 on page 319. In this machine not only does the segmental grinding wheel revolve on its spindle, but the spindle itself is mounted on a revolving carrier, so that the wheel will grind a surface double its own diameter. In this case, the diameter of the grinding wheel is 18½ in., while the surface covered is up to 36 in. in diameter. The machine is shown in end elevation facing the grinding head, in Fig. 57; Figs. 55 and 56 give respectively side elevation and plan; while Fig. 54 gives a general view of the whole, a closer view of the wheel being given in Fig. 58, which shows a set of engine cylinders mounted on the work-table. The bed of the machine is of box section. On this is mounted a saddle running, as shown in Fig. 57, on a V on one side and on a flat on the other. Flat gibs are used. On the saddle is mounted a 36-in. by 36-in. work-table with T-slots. This table is carried on a large circular face gibbed to the saddle. The four right-angle positions are located by a plug working in bushed holes in the table. The saddle is provided with quick-power traverse and the table is also rotated by power. An automatic trip is provided for the motion towards the wheel. The motion shafts are inside the bed instead of alongside, as in some previous designs. The power traverses are obtained by open and crossed belt drives with friction clutches. One gate change lever controls these motions. The segmental wheel revolving-carrier runs in a very

PLANETARY-HEAD SURFACE GRINDER AT THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY THE LUMSDEN MACHINE COMPANY, LIMITED, ENGINEERS, GATESHEAD.

Fig. 55.

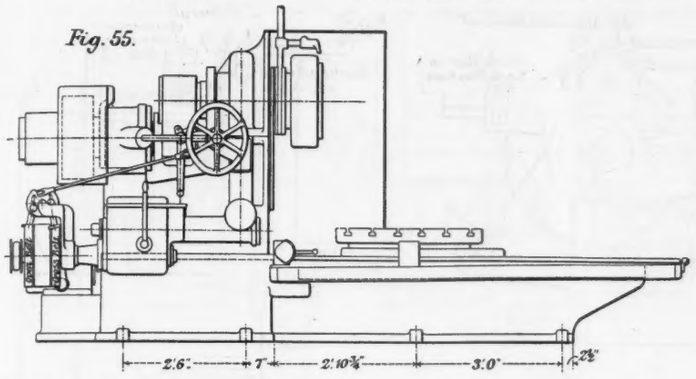


Fig. 56.

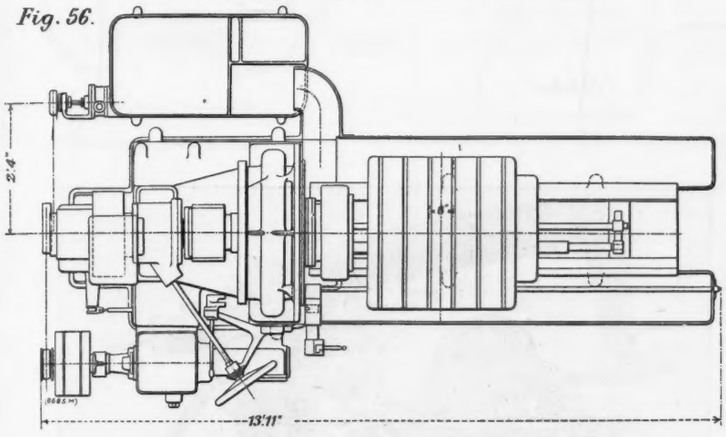
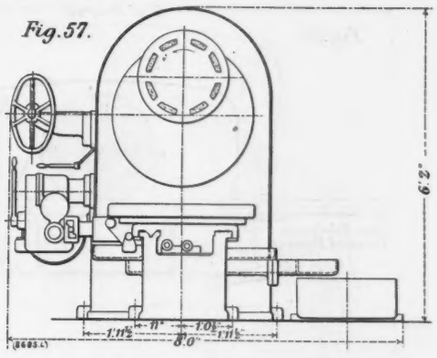


Fig. 57.



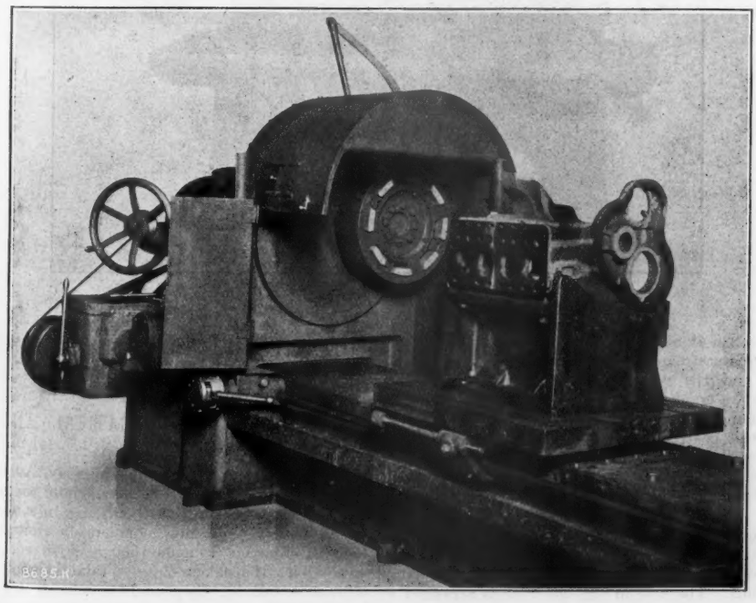


FIG. 58. ENGINE CYLINDER BLOCK MOUNTED ON PLANETARY-HEAD GRINDER.

heavy headstock. The wheel itself is carried on a spindle running in ball and roller bearings in a heavy cylindrical ram. This can be fed forward by a large hand wheel, shown at the front of the machine, the spindle of which runs diagonally to the headstock casting. The driving pulley is 20 in. in diameter and runs at 730 revolutions per minute. The belt used is 7 in. wide, and the horse-power to drive the machine is 25 brake. The drive to the grinding wheel is transmitted through the carrier centre by single helical gears, a telescopic shaft transmitting the belt drive to the centre gear wheel. A heavy spiral spring acts on a concentric plunger to take up end wear. The rotating motion of the carrier is derived from open and crossed belts to the same gear-box as is used for the traverses, the belt drive being taken, as shown in Fig. 53, from a pulley alongside the main driving pulley. The gear-box drive gives two speeds for the planetary motion and embodies friction clutches; the final drive to the carrier is by worm and worm wheel. The carrier can be continuously rotated or, alternatively, it can be oscillated over an arc of a circle, the latter motion being controlled through the belts by means of tappets mounted on a T-slotted ring attached to the carrier. High-speed shafts are in all cases mounted on ball bearings. A large centrifugal pump, belt-driven, is mounted at the back of the bed-plate to provide a copious supply of water to the wheel. The work is protected by very adequate splash-guards.

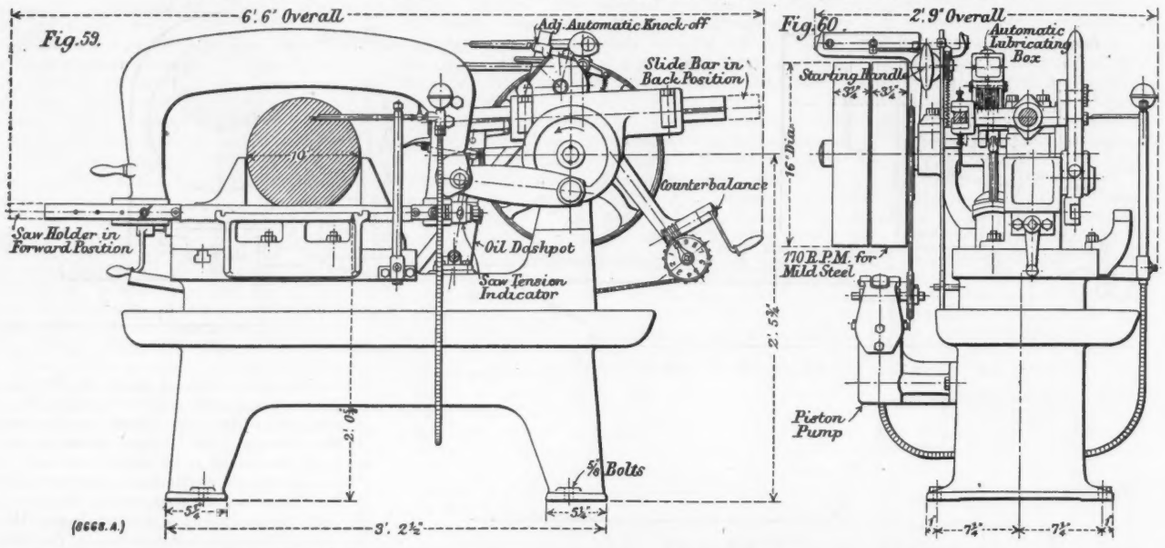
SAWING MACHINES.

A number of makers of sawing machines are represented by a good selection of tools. Messrs. E. G. Herbert, Limited, Levershulme, Manchester, show various sizes, including new patterns, as do also Messrs. Charles Wicksteed, Limited, of Kettering, while Messrs. Humpage, Thompson and Hardy, of Bristol, also have two models on show. Messrs. E. G. Herbert's exhibit includes their "Rapid" and "Rapidor" hack-saw machines, girder sawing machine and vertical sawing machine. Of their "Rapid" hack saws five machines are exhibited in different sizes, the smallest dealing with bars up to 6 in. by 6 in., while the largest is of capacity sufficient to handle billets 26 in. by 26 in. and using blades 24 in. to 39 in. long. This is naturally a substantial machine. It weighs no less than 3¾ tons. The girder saw is a light machine, using blades 18 in. to 22 in. long, intended specially for rolled sections. It is fitted with a vertical vice of special construction, arranged to swivel on a T-slotted bed, so that sections 20 in. by 12 in. can be cut square, or sections up to 20 in. by 7½ in. can be mitred vertically. The "Rapid" vertical saw of Messrs. E. G. Herbert has a capacity up to sections 12 in. high and 9 in. wide. This machine can perform a variety of work and is capable of displacing a certain amount of slotting work. The table, measuring 42 in. by 30 in., is mounted on a box base and the saw blades work through a slot in the table top. The saw frame is set at an angle of 45 deg. to the blade and oscillates vertically outside the table, so that the frame is always clear of the work either for longitudinal or cross cutting. The feed to the saw is 14 in., and by means of the table slide cuts 26 in. long can be taken at one setting.

Two of the firm's latest machines are examples of the "Rapidor" saws. The machine, illustrated in Figs. 59 to 61, page 320, has been developed to take full advantage of high-speed steel blades. The machine is exceptionally substantially built in order to stand up to heavy work with maximum output. The No. 2 size machine illustrated is intended for cutting sections 12 in. by 9 in. or rounds up to 10 in. in diameter, and takes saw blades from 14 in. to 21 in. long. It requires about 1 h.p. The fast and loose pulleys are 16 in. in diameter and the pulley speed is 170 r.p.m. The saw has automatic lift for the return stroke and

10-IN. "RAPIDOR" HACK-SAW AT THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. E. G. HERBERT, LIMITED, ENGINEERS, MANCHESTER.



spring gear for regulating the pressure of the blade on the work. The springs are housed in the body of the machine and the tension is transmitted by chain to a small drum on a tail piece. The drum is fitted with worm and handle for regulating the tension of the spring. An adjustable stop automatically holds up the machine at any depth of cut. Automatic mechanical lubrication is arranged for throughout. A dash-pot allows the frame to be lowered quickly or slowly or held at any point by the pressure of the finger on a lever. The machine starts on corners very easily. The tension on the blade can be regulated and an indicator shows when the correct stress is applied, thus tending to reduce breakages. The main shaft is hardened and ground and runs in renewable bearings. The crankpin is likewise hardened and ground. All wearing parts are provided with adjustment. The screw vice can be swivelled for taking angular cuts. When required for cutting mild steel and tool steel a two-speed countershaft or two-speed gear is required. The No. 1 "Rapidor" machine has a capacity for sections 6 in. by 6 in. and employs blades 10 in. to 14 in. long.

Two high-speed cutting-off machines are to be seen at the stand of Messrs. Humpage, Thompson and Hardy, of Jacob-street, Bristol, one being a 10-in. machine and the other a 10-in. by 5-in. machine suitable for joists, angles, channels, &c., and capable of cutting at any angle up to 45 deg. These machines are similar as regards many features. Figs. 62 to 64, page 321, illustrate the plain 10-in. machine, while Fig. 65 shows the saw for the square or angular cutting of sections. Both types have box beds, the former having a sloping vice rest, while in the latter this is horizontal. The main crank is double webbed and runs in bearings set wide apart. The saw frame oscillates in guides in a swinging arm which is forked at the crank end and carried in bearings, the spread of which ensure to the fork an unusual degree of lateral rigidity. The combined motion gives the saw a rocking movement instead of a simple back and forward straight stroke. The saw blade is supported on both sides by small roller guides mounted on eccentric pins so that the width apart of the guides can be adjusted to suit the thickness of the saw blade. This is a useful safeguard against "running off." Pressure is maintained on the blade by means of a long helical spring in the bed. Tension on this can be applied by a star wheel and screw at the front of the machine, a graduated plate indicating the pressure applied. By means of another star wheel at the back of the machine this spring pressure is relieved as the saw approaches the end of its work and lowest position, so that the final cutting through is accomplished by the weight of the arm alone. Just before the saw reaches the end of its stroke a cam motion lifts the swinging arm and the return stroke is made free. For setting, a crank handle and bevel gear are furnished for lifting the swinging arm to its highest position, and this gear is used for lowering the arm on to the work when commencing to saw. The saw blade is fixed at one end on an eccentric pin which can be rotated to apply the correct degree of tension.

The general motions and fittings of the two machines are similar. Fig. 65 illustrates the chief difference in the case of the machine for cutting sections. The vice in this machine is arranged so that the left-hand jaw can be swung through 45 deg. The right-hand or movable side is made of a fixed jaw bevelled to 45 deg., and an adjustable stop. The latter can be made to project whatever amount is required by the setting of the left-hand jaw, and the vice is then screwed hard up in the usual way. An end stop capable of adjustment, composed of rods and clamps is available for repeating cuts to length. This is shown in the drawings Figs. 62 to 63.

(*To be continued.*)

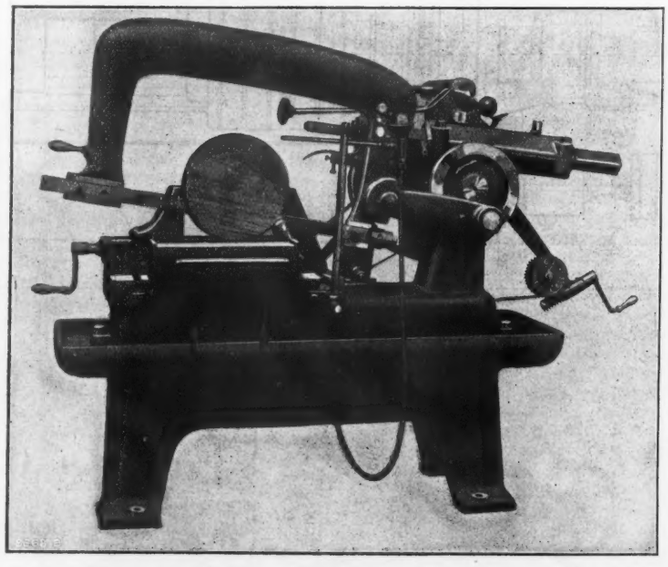


FIG. 61. GENERAL VIEW OF MACHINE.

THE BRITISH ASSOCIATION MEETING AT TORONTO.

(*Continued from page* 287.)

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PUNCTUALLY at 10 a.m., on Thursday, August 7, Sir William H. Bragg, F.R.S., President of Section A, opened the proceedings without any introductory words, merely requesting members, in view of the long list of papers, to make their remarks as concise as possible. If speakers chose to take their full time allowance talking, they could not have any discussion. The 45 items on the agenda comprised several groups of communications, and further papers were added. By taking the unoccupied afternoons, and by subdividing several times into a general Section and a Sub-Section for Cosmical Physics, Section A disposed of its whole programme in meetings which will remain memorable in the annals of the Association and of Science. Definite problems of the old controversy, renewed in our age, radiation by waves or by corpuscles, were keenly discussed by some of the very men who had raised

10-IN. HACK-SAWS AT THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. HUMPAGE, THOMPSON AND HARDY, ENGINEERS, BRISTOL.

(*For Description, see opposite Page.*)

Fig. 62.

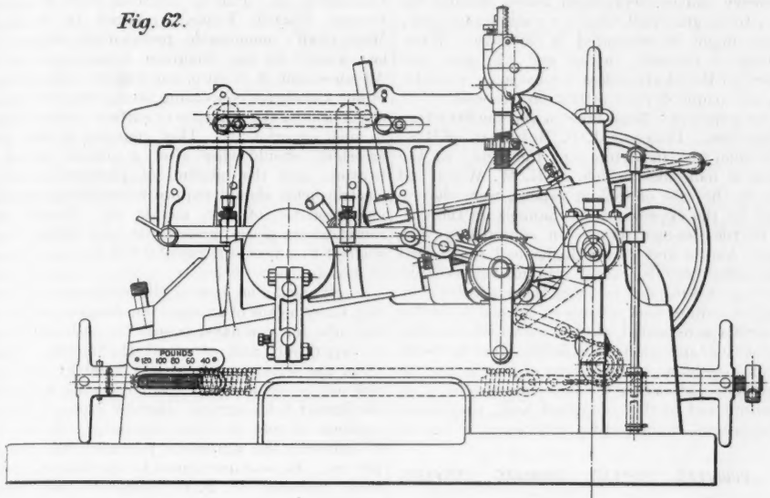


Fig. 64.

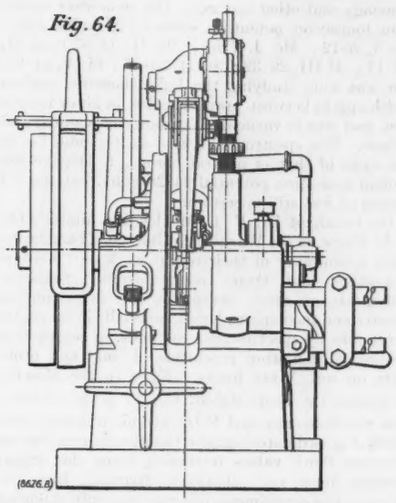
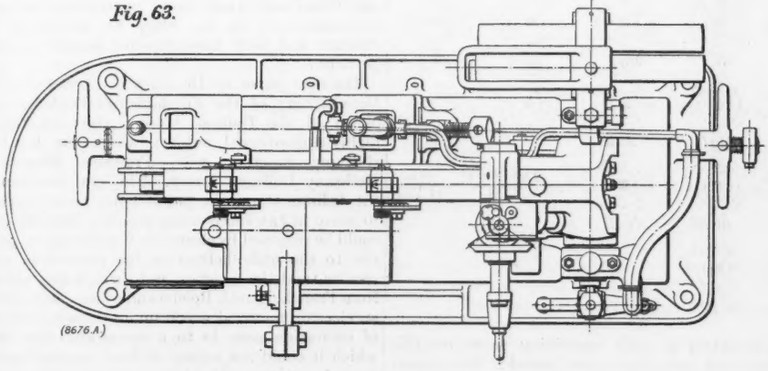


Fig. 63.



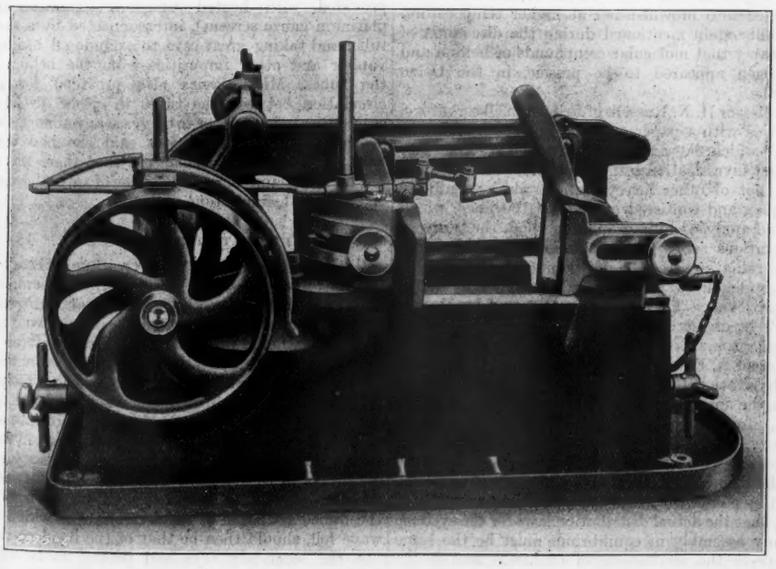


FIG. 65. SAW FOR CUTTING ROLLED SECTIONS.

them. American scientists contributed much to the success. Continental science was not represented, but their work was not ignored; no time was wasted in complimentary generalities.

The sectional officers were Professor A. O. Rankine (South Kensington), recorder, and Messrs. M. A. Giblett (Air Ministry), H. R. Hassé (Woolwich), J. Jackson (Greenwich Observatory), A. M. Tyndall (Bristol), and E. F. Burton (Toronto). The first subject taken was Spectra, Ionisation and Cognate Phenomena; similar problems came up later, on the Friday and Tuesday of the meeting, in the discussions on the Scattering of Light. We will deal with these papers first, proceeding then to papers on Crystal Structure, which were introduced by the presidential address, on Cosmical Physics, Meteorology and Astronomy, and to papers interesting to engineers on Acoustics and other subjects.

SPECTRA AND THEIR EXCITATION, IONISATION AND CRITICAL POTENTIALS.

Summarising in the first paper on "The Spectra of Ionised Elements," recent work on ionised and on multiply-ionised atoms, Professor A. Fowler, F.R.S., explained that ionisations were produced by the application of increased amounts of energy, and the qualitative and quantitative data on series lines were valuable for the study of atomic structure and for astrophysics, especially for the estimation of stellar temperatures and densities. The spectra of the elements of the same group had much in common; group I (alkali metals, sodium, &c.) was distinguished by doublets, group II (magnesium) by triplets, group III (aluminium) again by doublets, and so on; but matters were more complex than this simple alternation formerly assumed. When, however, a neutral atom was ionised by losing an electron, its spectrum went back to that of the next element of lower atomic number; thus, the spark spectrum of the ionised magnesium atom Mg 12 recalled the arc spectrum of the neutral sodium, Na 11; with two electrons lost the spectrum went back two places (Al 13 to Na 11). The series constants C of all the neutral atoms, *e.g.*, Si, were nearly the same as that of hydrogen ($C = N$); when the atom was singly ionised (spectrum indicated by Si I) its constant assumed the fourfold value ($C = 4N$); when doubly ionised (Si II) $C = 9N$; when trebly ionised (Si III), $C = 16N$. The confirmation of this rule, first established for helium and the alkali metals, for magnesium (by Paschen) and for aluminium and silicon (the most complete exploration of successive ionisation so far attained) by Professor Fowler himself was essential for Bohr's quantum theory of spectra.

To explain the effect of successive losses of electrons or, conversely, of adding electrons to the nucleus, S IV to Si I) Professor Fowler exhibited the diagram on the next page. The constant C was given by $C = 2\pi^2 E^2 m M (n e)^2 / c h^3 . (M + m)$, where e was the charge of the electron, E the net charge on the remainder of the atom with respect to the external electron, temporarily removed, h was Planck's constant, c the velocity of light, and M and m were the masses of the atom and electron. In passing from Si IV to Si I, the effects of adding external electrons one by one were exhibited under somewhat simpler

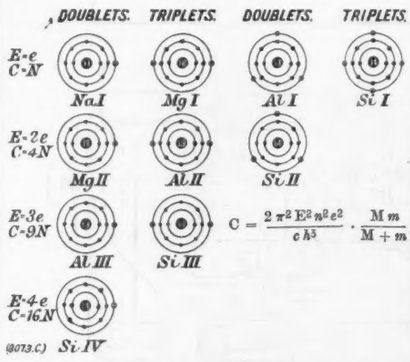
conditions than in the regular sequence of the neutral atoms of Na, Al, Mg, Si, since the mass and charge of the nucleus remained constant. Professor Fowler's further slides showed that the well-known D lines of sodium, Na I, were repeated in Mg II, Al III, Si IV, but with increasing intermediate spacings, and other features. The somewhat uncertain ionisation potentials deduced in volts were: Na I, 5·12; Mg. I, 7·61; Mg II, 14·97; Al II, 18·11; Al III, 28·32; Si III, 31·66; Si IV, 44·95. He was now studying the light elements, carbon (with sparks between graphite poles, in air or hydrogen, and arcs in vacuo or in carbon compounds) and others. The spectrum C I was, as it should be, of the type of that of neutral boron; C II gave the second ionisation potential 24·28 volts, but the C I potential was still uncertain.

On behalf of Dr. F. L. Mohler and himself, Dr. P. D. Foote, of the Washington Bureau of Standards, gave a summary of their recent work on "Critical Potentials and their Interpretation," radiation potentials of gases, stages in the excitation of spectra and their energy levels, especially in ranges inaccessible by spectroscopic methods, in comparison to critical radiation potentials of solid and other data on soft X-ray limits. When in the Moseley diagrams, Dr. Foote stated, the $\sqrt{\nu}/N$ (where ν was the frequency and N the atomic number) were plotted as ordinates against the atomic numbers as abscissæ (both values increasing from the origin) straight lines were obtained, diverging from the origin. But direct measurements had only extended down to ordinate 10; below that value the lines were not straight and convergent, and the Moseley regularity observed for high frequencies did no longer hold. Dr. Foote's slides showed lines of high and low energy levels, from the K and L series down to the M, N, O, P and Q series, the latter belonging to elements of very high atomic numbers.

When radiations were excited by electron impacts with solids at relatively low volts (photo-electric effects), the photo-electric current increased sharply at certain potentials. It had been assumed that these critical voltages measured the low-volt X-ray level, and the authors had made similar observations on gases and vapours. In the X-ray range the predominant type of excitation was single ionisation; in low-volt impact, excitation without ionisation was the most probable event, yet spark lines could also be excited readily. While some carbon compounds had all given the same critical potential of 272 volts in the vapour state, other experimenters had found 288 volts for solid carbon; that difference between data on gases and solids was not yet explained. In alkali vapours a many-line spectrum (the argon spark spectrum) appeared above 20 volts. The excitation would involve either removal of two electrons or removal of one electron and displacement of another, and one single impact might eject two electrons or only one, which was struck again before reverting to its normal condition. The potential required to remove the second electron of a rare gas was found nearly equal to the potential required to remove the first electron of the rare gas shell of the neighbouring alkali metal; it was, *e.g.*, 19 volts for argon and for potassium. With respect to the work on the bombardment of targets of carbon, copper, iron and platinum with electrons at velocities corresponding to 500 volts and 1,000 volts, we will only mention that many new lines were observed, but were all ascribed to impurities, and, further, that nitrogen at 1,000 volts did not give the auroral line, but showed a peculiar new type of line spectrum when the gas pressure was reduced below 0·002 mm. of mercury (again probably owing to impurities) and, in addition, a continuous spectrum, already observed by Lilienfeld.

Dr. Foote finally referred to some peculiar observations of theirs. Freshly-distilled calcium proved sometimes highly explosive on exposure to the atmosphere. Arsenic vapours did not become luminous when large currents were passed through them, the spectrum being confined to the ultra-violet; for actinic work arsenic vapour lamps might hence be useful. The arc or the spark spectrum of alkali vapours and also of iodine vapours could be excited with the electrodeless ring discharge simply by varying the temperature or vapour pressure. In the ring discharge the potential gradient was greatest at the circumference of the bulb and diminished to zero at the centre; thus, various degrees of excitation could be produced simultaneously, and concentric rings of brilliant colours were observed. In a large bulb containing mercury vapour the area near the conducting ring became a mercury mirror, centrifugal forces driving the ions up to the glass wall, where they were condensed; isotopes might be separated in this way. When mixtures of mercury vapour and nitrogen were exposed to the electrodeless discharge in a quartz bulb, an opaque deposit settled on the walls.

In his paper on "Band Spectra and the Structure of Molecules," Professor J. C. McLennan, F.R.S., dwelt upon the importance of the study of the spectra of molecules, which, as R. W. Wood had shown in the case of sodium vapour, were characterised by the appearance of channels on the outside of the doublet series. In conjunction with Messrs. Ainslie and S. Smith, he had found that all the alkali metals, except lithium, behaved like sodium in this respect, and that the molecular compound of sodium and potassium, formed when the two metals were heated, also gave a vapour showing the molecular spectrum. Calculating, from the bands at high dispersion, the moments of inertia and the interatomic distances in the molecules of sodium, of potassium and of the compound NaK, they found the expected characteristic differences. In the



demonstration a bulb containing some metallic sodium and potassium was heated; the vapour first appeared dull white in colour, but the colour changed into brownish-red at higher temperature. Dr. Silberstein mentioned during the discussion of the paper that molecular compounds of helium and hydrogen appeared to be present in the Orion Nebulæ.

Professor H. N. Russell, of Princeton Observatory, followed with a paper on the "Spectrum of Titanium," which, he said, had been much studied since its first investigation by A. Fowler. The spectrum, like that of other heavy metals, was exceedingly complex and consisted of about 1,100 lines, which he had analysed by a graphic method, the terms of the various series being found as intersections of lines radiating from eight points in the case of titanium; those points were connected with the energy levels. The paper was discussed by Messrs. G. Breit, of the Bureau of Terrestrial Magnetism, Washington, P. D. Foote, R. H. Fowler, and by Professor A. Fowler, who testified to the high value of the exact determinations by Professor Russell.

In the next paper on "the Mechanism of Excitation, Ionisation and Dissociation in Statistical Theory," Mr. R. H. Fowler, of Cambridge, pointed out that we were in great ignorance as to the mechanism. Two hypotheses supplied possible starting points. (*a*) The hypothesis of preservation, viz., that the actual distribution laws for the systems in any assembly in equilibrium must be the same whatever the mechanism of exchange, and (*b*) the hypothesis of detailed balancing, that in equilibrium the effects of any specified process must be balanced by another, its exact reverse differing only in a reversed time scale. Examining a number of mechanisms in the light of these hypotheses, of which (*b*) was more restricted than (*a*), and referring in the first instance to Einstein's classical paper of 1917 on collision, Mr. Fowler discussed excitation by collision (following Klein and Rosseland), ionisation by collision (Becker), excitation by radiation (Einstein), and scattering by free electrons (Einstein and Ehrenfest), and the photo-electric effect (Kramers and Milne).

The paper by Dr. R. J. Piersol, of Pittsburgh University, on "Pulling Electrons from Metals by Intense Electric Fields," referred to Professor Mendenhall's memorable presidential address (of last winter) to the American Association for the Advancement of Science, and to the confused state of our knowledge concerning thermionic emission of electrons and the influence of surface contamination in such experiments. That emission, it had been asserted, should stop after a certain period of heating, and the ejection of photo-electrons by electric fields should require a minimum potential characteristic of the metal. Dr. Piersol used molybdenum plates pressed into two hemispherical shells with a discharge gap of 0·023 cm. as electrodes of his discharge tube, to which a charcoal bulb was attached; he heated the electrodes to 1,400 deg. C. by means of an induction furnace, evacuated the tube for two days, cooled the charcoal finally in liquid air, and observed thermionic currents when the vertical gradient was 5,400 kv. per cm.; this was to show that proper outgassing completely eliminated field currents, thereby giving a definite gradient of cold electronic discharge. In the case of calcium, the minimum potential was 200 kv. per cm. He was questioned by Sir Ernest Rutherford, Professors W. F. G. Swann of Yale College, and Wood and others as to his current and their measurements; in his reply he attributed the currents and their measurements largely to anode particles.

The next paper by Dr. Anne C. Davies on "The Metastability of the Fundamental Coplanar Condition of the Helium Atom," also concerned a highly-controversial subject which she has been studying together with Professor Horton at Holloway College, Surrey. The two electrons of the helium atom, she pointed out, were supposed to move in two intersecting planes; both electrons could be removed by electronic bombardment, giving rise to the ortho-helium or the par-helium series spectra, and the question as to which they differed from Franck, Landé, Reiche and others, was whether an electron removed would under certain conditions of excitation pass in to a metastable state from which it could not return without external agents. Experimenting with two vertical tubes (both provided with heated tungsten filaments and platinum gauze screens), interconnected by a short tube, and taking great care to exclude all mercury vapour and other impurities from the helium in the tubes, Miss Davies also provided for gas circulation between the tubes in either direction, so as either to increase or to decrease any abnormality of the helium. Miss Davies said she had come back to her original conclusion that there was no reason to assume a metastability of any abnormal state of the helium atom.

The Scattering of X-Rays.

With his paper on "The Quantum Theory of the Scattering of X-Rays," Professor A. H. Compton, of Chicago, brought up the fundamental controversy which his own experiments first raised two years ago, and which, in his opinion, would force us to abandon either the idea that radiation spreads in spherical waves in all directions, or the principles of the conservation of momentum and energy. Mr. Compton stated that Barkla's experiments and J. J. Thomson's theory—neither of these investigators was present—had considered the scattering of X-rays to be in accord with the electromagnetic wave theory. The frequency and wave-length of the forced radiation of an electron, upon which the wave fell, should then be that of the incident ray; but the secondary rays had proved to be softer (of less penetrating power), especially in the case of electrons from the light elements. When Mr. Compton examined the phenomenon spectroscopically he found that the incident ray was split into two, one of the original wave-length, the other of greater wave length. He let tungsten rays fall at 90 deg. upon a crystal of graphite (the radiator), and observed a displacement of the one ray by

0·024 A.U., which was in accord with his later calculations. Further experiments at different incidences showed that the displacement increased with greater angles of scattering. If that had been a Doppler effect, all the electrons should be effective and should have moved in the direction of the primary ray with a velocity approaching that of light, which was obviously contrary to fact. Only a very small number of electrons could be responsible for the scattering. On the quantum theory an electron, if it scattered at all, would scatter a whole quantum. But as the scattered secondary ray proceeded in a different direction, it would have different momentum, and, by the principle of the conservation of momentum, the electron must recoil with a momentum equal to the vector difference between that of the primary and that of the scattered quanta. The energy of the recoiling electron being taken from the primary quantum, the scattered quantum was left with reduced energy and diminished frequency.

Since Compton had first proposed this explanation both C. T. R. Wilson and W. Bothe (Reichsanstalt) had independently observed (by the cloud-expansion method of Wilson) a new type of secondary β-rays which they had identified as recoil electrons. The displacement should also be visible with light rays, but had not yet been observed. One might, however, look for a change in wave-length in the dissociated atmosphere of the sun where it should be greater near the limb than near the centre of the disc because the light from the limb travelled through a thicker layer of electrons; that had long been observed and was supported by the thermo-dynamical considerations of Pauli. With regard to light, the quantum might, further, be large enough to fall simultaneously upon a group of electrons, to be scattered by the group, similarly as light was reflected or scattered by a group of electrons in a mirror; in that case the mass of the group would be so great that the energy lost in the recoil would be insignificant and the change in wave-length negligible. That agreed with experiments by himself and also by E. Rutherford. If, on the other hand, the wave-length were much smaller than the distance between two adjacent electrons, as in the case of hard γ-rays, each quantum should be scattered by individual electrons and give rise only to a ray of modified wave-length. Quantitative confirmations of the various cases had been obtained by P. A. Ross, who had, however, to use photographic exposures of up to 250 hour in some instancee, whilst Clark and Duane (presently to be mentioned) failed to do so. Professor Compton also referred to his most recent photo-electric work.

Professor J. A. Gray, of McGill University, Montreal, followed with a paper on the "Scattering of X- and Gamma Rays and the Production of X-Rays by Photo-electrons." He described experiments in which he made monochromatic X-rays strike a cylinder of paraffin, or rays from radium (filtered through a thin foil of lead and through several millimetres of carbon) enter an electroscope; he found these special secondary rays to be softer than the original rays, and he concluded that ultimately X-rays passing through matter would be transformed into β-rays by alternating changes from X to β, back to softer X-rays, and so on. The greater portion of the secondary rays was not due to the photo-electrons ejected from matter, but had its origin in the scattering of the primary rays, the softening of scattered rays increasing with increasing atomic weight. Commenting upon this paper, Sir E. Rutherford remarked that the internal conversion was enormously greater than had been expected.

Professor W. Duane, of Harvard College, then gave his paper on "Secondary and Tertiary Radiations," describing the latest experiments made by himself and Doctors Allison, Clark and Stifler, in which the X-ray bulb was placed in a large room and radiated through a hole in the wall into the spectrometer mounted in a second room. They then observed radiations of three kinds, scattered, fluorescent and tertiary (due to the bombardment by photo-electrons), but they obtained no Compton displacement, except when they encased the X-ray bulb in a lead box instead of a wood box. They further obtained spectroscopic evidence of the reflection (by a crystal of potassium iodide) of X-rays characteristic of potassium and iodine. Copper screens cut off nearly all this characteristic reflection; that, however, they considered, did not indicate an increase in the reflecting power of the crystal for certain rays already in the beam, but rather the generation of a fluorescent radiation in the crystal by the X-rays.

These communications on scattered rays and their interpretation, and on the experimental detail, were further discussed in a special long afternoon meeting, under the presidency of Professor A. B. Eve, of McGill College, by Professors D. L. Webster (of Stanford University, California), Breit, Swann, Compton, Gray and others, some of whom agreed with Compton that the box and its material had nothing to do with the range of wave-length. Professor Raman (Calcutta) rejected the quantum theory.

(To be continued.)

THE PEEBLES-REYROLLE AUTOMATIC SUBSTATION.

THE great drawback to the use of direct current for tramway or railway purposes lies in the necessity for a large number of isolated substations for converting the alternating current supply to direct current at the voltage required for use. Such substations must contain running machinery, and until recently the control of this machinery has required the personal attendance of skilled operators during the whole of the time that the supply is maintained. For the greater part of the time the operators, of course, have absolutely nothing to do except to stand by, and the employment of two or three shifts of men per day on such duty in each substation involves an expenditure in wages quite disproportionate to the services rendered. Under these circumstances, it is not surprising that attempts have been made to render the operation of these substations automatic, so that the equipment will start up, perform its functions and shut down without the presence of any human operator. Apparatus working under such conditions must not only be self-protective, isolating itself from the system should any dangerous internal symptoms arise, but it must also protect the system as far as possible from the effect of external faults. The requirements are both onerous and complex, but they can now be satisfactorily met, and the fully automatic substation has become a recognised factor in electrical distribution.

The essential feature of substations of this nature lies in the automatic switchgear which controls the machinery, but this, of course, must be designed in accordance with the characteristics of the machinery to be controlled. Messrs. A. Reyrolle and Company, Limited, of Hebburn-on-Tyne, who are well known as the originators of the metal-clad switchgear now generally used in the large modern power stations, decided some time ago to apply this type of gear to automatic substation work in connection with the standard motor-converting machinery of Messrs. Bruce, Peebles and Company, Limited. Messrs. A. Reyrolle and Company made a close study of the whole question as a result of which they have produced the necessary apparatus to deal with any operating condition, and the collaboration of these two firms has resulted in the production of a completely automatic substation capable of performing all the functions which usually demand the intervention of a skilled operator. There have been, of course, fully automatic substations at work for some time in this and other countries, but the earlier attempts to solve the problem involved considerable complications of apparatus and required a large amount of space. As experience was gained, steady progress was made with simplification, and in the Peebles-Reyrolle automatic substation the designers have attained a degree of simplicity and a compactness of the necessary apparatus which is much to be commended. The controlling switchgear is an adaptation of Messrs. Reyrolle's metal-clad type with electric control, and all the individual relays and devices by means of which a predetermined set of conditions causes the starting or stopping of the machine are designed in the light of the firm's long experience with automatic protective apparatus. It may be added that the space taken up by the complete equipment is less than half that required for other types.

The Peebles-Reyrolle automatic substation is a single-unit station, for it is probable that the single-unit station will be generally adopted in the future for automatic working, on account of the economy in copper and the improvement in voltage regulation arising from the better distribution of the converting plant over the system. A motor-converter with its own control equipment constitutes a unit, and a double unit station, if such were required, would consist of two such units. In a fully automatic substation, the Peebles-Reyrolle service equipment permits of manual operation by an attendant at any time if desired. He can start and stop the machinery, conduct the switching operation on both the direct current and alternating current circuits, synchronise, and regulate the voltage at will. Starting and stopping of the substation may also be effected from the main station or any other distant point if a pair of pilot leads are available. In such cases the substation is called semi-automatic. A further alternative is to arrange for distant control of other functions such as voltage regulation, the operation of the machine circuit breakers, the prevention of the plant shutting down automatically on underload or the prevention of it taking up its work automatically when it otherwise would do so.

The motor-converter, rather than the rotary-converter, was chosen for the automatic substation on account of its special advantages for such work. The machine, as is well known, consists of an ordinary wound-rotor induction motor and an ordinary continuous-current generator coupled together mechanically on the same shaft, the rotor winding and the armature winding being interconnected electrically. The combined rotor and armature runs at a speed corresponding to half the frequency of the alternating-current supply, *i.e.*, with a slip of 50 per cent. Currents are therefore induced in the rotor winding which also have a frequency equal to half that of the supply. The number of poles of the continuous-current generator is so arranged that the frequency of the currents induced in the armature winding at the normal speed of rotation is equal to that of the induced rotor currents. It is therefore possible to interconnect the armature and rotor windings when their E.M.F.'s are equal and in phase. When this is done the whole set behaves as a single-synchronous machine, with strong synchronising forces. As the rotor revolves at a speed corresponding to half the frequency of the supply circuit, only half the alternating-current electrical energy is converted into mechanical energy for driving the dynamo, the other half is transferred in the form of electrical energy. As the size of the alternating-current end depends on the speed of the rotating field and not on the speed at which the rotor runs, the induction motor is only about half the size of the corresponding motor of a motor-generator set. Furthermore, the direct-current end, running at a speed corresponding to half the primary frequency, has not only particularly good commutating conditions, but is of smaller proportions than an ordinary continuous-current generator or rotary converter for the same output, frequency, and speed.

The motor-converter has, as will be seen, all the mechanical and electrical advantages of a low-frequency machine, as it runs generally at a speed corresponding to half the supply frequency. The difficulties inherent in the design of rotary converters for standard and higher frequencies are absent, and the increased brush-spacing permitted by the reduced number of poles reduces the danger of flashing-over to a negligible quantity. Transformers are not needed in conjunction with the machines, as the ordinary transmission voltage can be put on to the stator of the induction motor. The very strong synchronising properties of motor-converters prevent these machines from falling out of step and shutting down in the event of disturbances on the electrical system, which would almost inevitably put rotaries out of commission. Their automatic balancing properties when serving a three-wire network, their irreversibility in the event of severe short-circuits on the direct-current system, their high power-factor, and their capacity

THE PEEBLES-REYROLLE AUTOMATIC SUBSTATION; EMPIRE EXHIBITION.

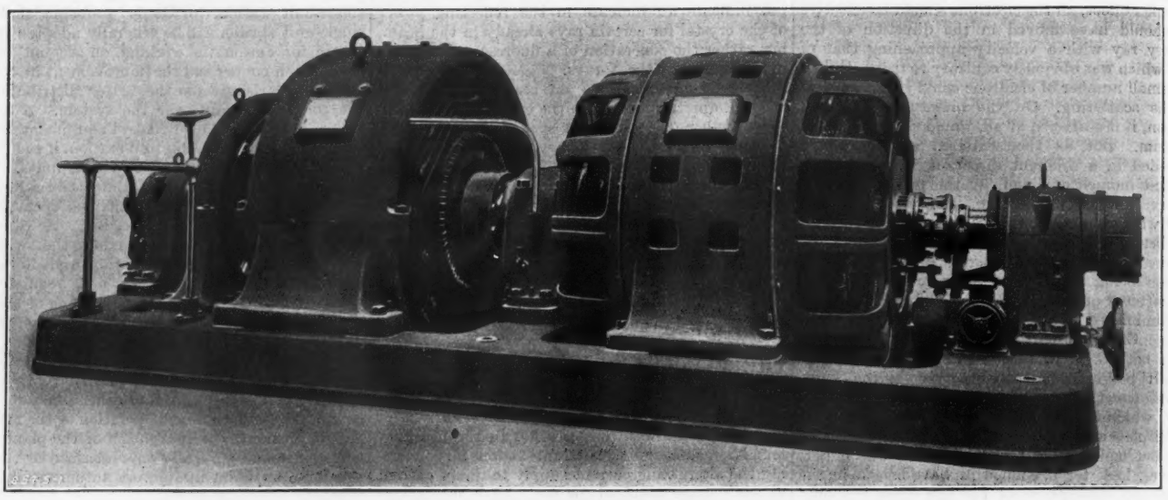


FIG. 1. 500-KW. BRUCE PEEBLES MOTOR CONVERTER.

for voltage regulation are other features which render them specially suitable as components of an automatic plant.

The complete equipment for a Peebles-Reyrolle automatic substation for tramway work or other two-wire D.C. traction comprises the motor converter with its starting resistance illustrated in Figs. 1 and 2 on this page, the metal-clad switch panel illustrated in Fig. 8 and the three control panels in Fig. 9, page 330. Figs. 10 and 11 on the latter page show respectively the high-speed circuit breaker panel open, and an enlarged view of the time relay. These also are on page 330, and in Figs. 3 to 7 on succeeding pages are details of the connections and mechanism. The diagram of connections, Fig. 3, necessarily appears somewhat complicated, but considering the variety of functions to be performed and the diversity of conditions to be dealt with it is by no means unduly so. The equipment as illustrated will permit of three methods of operation, namely, fully automatic working, hand starting and stopping, and entire manual operation by an attendant. The addition of one pair of pilot wires also enables the plant to be operated from some other place.

The automatic starting of the plant may be brought about either by means of a reduction in voltage on the D.C. system which the station is to feed, by a predetermined demand for current on that system, or by a switch set to operate at a given time. In a single unit traction substation a starting device consisting of a low-voltage relay and a time switch will meet most conditions of service. As it is important that the station should not be started for every momentary drop of voltage that occurs on a traction system, the action of the low-voltage starting relay is retarded, so that the condition of low voltage must persist for a definite time before the plant begins to run up. The setting of the time switch that determines the delay can be adjusted, so that any time from five to thirty seconds must elapse before the plant starts. The persistence of low-voltage for such a length of time is sufficient indication that the substation plant is required, and that it will have an economical load when it is switched in. At the end of the time, the starting up device continues to run long enough to allow the plant three attempts to get on load unless it is previously re-set by the functioning of other apparatus.

After a sufficient time for the plant to have got on load, if it should not have done so, the master control circuit is automatically opened, the plant is shut down and the devices employed in running up are de-energised. This having been done, the master control circuit is immediately re-closed, and the operations necessary to put the machine on load are again carried out. Should this second attempt fail to get the machine into service it is again shut down and a third attempt is made. After this attempt, if the machine is not on load, it is finally shut down and locked out of commission, an alarm circuit being closed, which will transmit news of the failure to the central station if pilot wires are available. It may be mentioned at this point that the substation is automatically shut down and locked out by the action of various protective devices, so that it cannot be operated in a dangerous or unfit condition, whether that condition has arisen when working or when at rest. It will be locked out, for example, by an overload on the A.C. incoming feeder, indicating either an electrical fault or something seriously wrong with the machinery. Similarly, should the temperature of the bearings or the machine-windings rise beyond a predetermined limit, this will also cause a shut-down, and the same result will follow an abnormal speed of the machine. The plant will in all cases be locked out until deliberately put again into commission, except in the event of the shut-down being due to an undue temperature

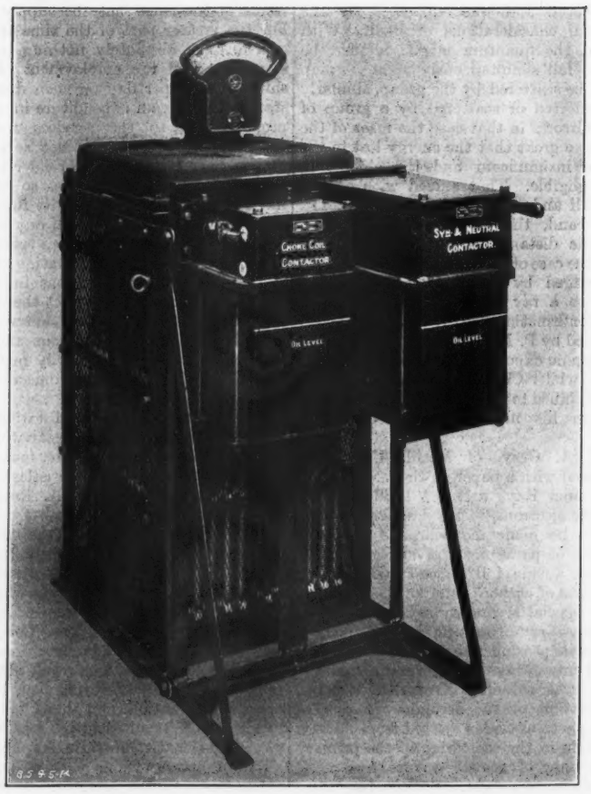


FIG. 2. STARTER FOR AUTOMATICALLY-CONTROLLED MOTOR CONVERTER.

rise of the windings, when the equipment will automatically become again available for duty after the machine has cooled down. A further cause of an automatic shut-down is the absence of a predetermined minimum load on the D.C. side for a predetermined period. In such a case, the station having nothing to do, shuts itself down, but is, of course, ready to start again automatically as soon as the demand is renewed. Conversely, a continued overload on the D.C. side will bring out the D.C. circuit breakers and the station will again be shut down until safe conditions of operation are restored.

Referring now more particularly to the automatic equipment of the Peebles-Reyrolle system, the run-out along the rails provided for the purpose. Mechanical interlocking arrangements prevent the switch being withdrawn or replaced unless it is open, and there is no possibility of any workman or other person touching or even seeing live metal unless he deliberately goes to a great amount of trouble to do so. The bus-bars and other internal conductors are embedded in solid insulation and protected by the earthed cast-iron casing, thus making the switch as safe as anything can well be.

In Fig. 9 will be seen three panels, two control panels on the left and a metal-clad D.C. machine panel on the right. The left-hand panel carries most of the relays necessary for the automatic operation of the system. At the top of the panel until the low voltage has endured long enough to show that it is not a mere transient symptom. An adjustable pause of from 5 to 30 seconds is provided to meet this condition. Similarly an adjustable pause of from 3 to 12 minutes is provided before the plant shuts down on account of under load, and an adjustable pause of from 5 to 60 seconds before it shuts down to protect itself from overload. The pause of from 3 to 12 seconds for synchronising allows sufficient time for that operation, and if it cannot be done in this time by the third attempt there is evidence that something is wrong, and the plant is automatically shut down and locked out of commission until it receives attention, as already mentioned.

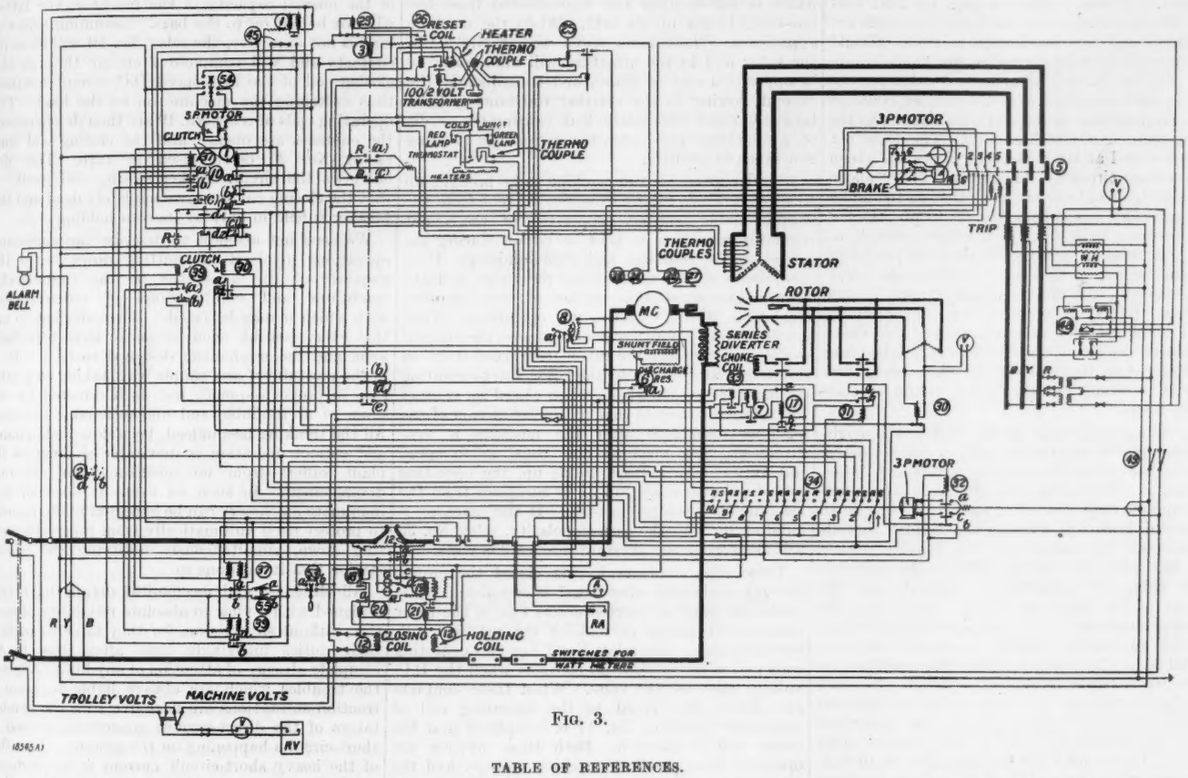


FIG. 3.

TABLE OF REFERENCES.

1. Starting-up relay.
2. Control switch—automatic to manual operation.
3. Master control relay.
5. Main oil switch fitted with charging resistances.
6. Shunt field make contactor.
7. Choke coil relay.
8. Shunt regulator.
10. Multiple time delay relay.
12. High-speed circuit breaker.
17. Choke coil contactor.
18. Bridging resistance contactor.
19. Load discriminating relay.
20. Closing coil contactor h.s. circuit breaker.
21. Holding coil contactor h.c. circuit breaker.
23. Low a.c. voltage relay.
25. Reverse current relay.
26. Stator temperature relay.
27. Over-speed device.
28. Bearing thermostats.
30. Synchronising relay.
31. Slip-ring s.c. contactor.
32. Rotor s.c. motor relay.
33. Polarity relay.
34. Auxiliary switchbox slip-ring s.c. mechanism.
1 S. Master control "starting up."
1 R. Master control "running."
2 S. Starting up—"motor and clutch."
2 R. Underload and o.l. clutch.
3 S. Starting-up clutch.
3 R. Underload and o.l. clutch.
4 S. Slip-ring s.c. contactor.
4 R.
5 S. Choke coil and relay contactor.
5 R. Bridging resistance and discriminating relay.
6 S. S.C. gear motor closing.
6 R. S.C. gear motor opening.
7 S. Synchronising relay.
7 R.
8 S.
8 R. Shunt field contactor.
9 S.
9 R. Shunt regulator, section s.c. connection.
10 S.
10 R. Stator temperature device, resetting coil.
37. Underload relay.
39. Overload relay.
45. Time Switch.
48. A.C. overload and earth leakage relay.
49. D.P. switch 110 volt. a.c. supply.
53. Control switch h.s. circuit breaker.
54. Control switch, starting and stopping.
55. D.P. switch underload relay cut-out.

high, or extra-high tension three-phase current entering the substation is brought to the Reyrolle metal-clad panel fitted with a voltmeter and integrating watt-meter, illustrated in Fig. 8. The panel contains the electrically operated main oil switch, with overload and earth-leakage protection, and a potential transformer is fitted on the incoming side of the switch. This transformer provides power for operating the A.C. devices employed in the equipment. The main oil switch is operated by a three-phase induction motor, and consequently cannot be closed unless all three phases are alive. It is opened under normal conditions by energising a tripping coil circuit, but a low-voltage tripping coil brings the switch out in case of overload on the A.C. feeder, leakage to earth, failure of the A.C. supply or the operation of any of the protective devices. The switch-operating motor will be seen on Fig. 8 immediately above the bus-bar chamber. The switch contacts are in the oil-tank at the back, and the whole switch can be withdrawn from connection with the bus-bars and is an indicating pyrometer showing the temperature in the stator. Next below this come a series of eight glass-fronted instruments, the upper one on the left-hand side being the master control switch which starts up the plant. Across the centre of the panel are three switches, the left-hand one being used to prevent the plant automatically shutting itself down on underload, so that it may be run idle when desired. The right-hand switch determines by its position whether the plant shall be under automatic or manual control, and the central switch is the manual starting switch. Below these three switches is a large instrument, seen more clearly in Fig. 11. This, which is called the "multiple time delay device," has the duty of causing a period of waiting before each of the four following operations, namely, starting up, synchronising, overload shut-down and underload shut-down. The necessity of such delay is obvious. Although the plant must start up automatically when the voltage of the D.C. system is low enough to need extra generating machinery, it must be prevented from starting

The mechanism of the multiple time-delay device consists of a clutch and gearing, by means of which a set of cams is rotated, and a series of contacts made or broken as required, in the proper sequence and after predetermined intervals of time. The fundamental timing depends on the speed of a small three-phase motor, which, as seen in Fig. 11, drives a horizontal spindle through double-reduction worm gearing at a constant speed of 3 revolutions per minute. The time-delay apparatus is shown diagrammatically in the upper left-hand part of Fig. 3 above. To avoid confusion of circuits all apparatus belonging to the same device is given the same number on the diagram. Underneath the motor of the time-delay starting apparatus is seen a clutch marked No. 1. This operates in conjunction with the starting-up relay No. 1 above it to the right. Similarly, clutches Nos. 30, 37 and 39 operate in conjunction with similarly numbered relays, for synchronising, underload and overload conditions respectively. A resetting mechanism R permits the station to be readily put into

commission again after having been locked out. The act of resetting can be performed electrically from the control station, if pilot leads are available between that station and the substation. The same leads will suffice both for this operation and for giving the alarm in the control station if the sub-station is locked out.

Referring again to the left-hand upper portion of the diagram, it will be seen that the contacts on any one mechanism are stepped and grouped to indicate the sequence of the operations. In the case of the device No. 1, for example, contact (a) is made immediately the mechanism starts to move. After a delay of from 5 to 30 seconds, depending on the setting, contacts (b_1) and (b_2) are closed simultaneously. If the substation goes on load normally, the respective motor and clutch circuits are interrupted and this mechanism is reset. Should the mechanism continue to run on, due to the failure of the plant to get on load or for any other reason, after the full time setting of 5 to 6 minutes, contacts (c_1) and (c_2) operate to interrupt the circuits to the starting motor and clutch circuits. This locks out the station and at the same time closes the alarm and resetting circuits. "Lock-out" and "alarm and resetting" contacts are also fitted on the under load time-delay mechanism, No. 37 to prevent the plant running light for an indefinite period, as might otherwise happen should there be persistent fault conditions on the direct-current side which would prevent the direct-current circuit-breaker reclosing. It may be noted that no motor circuit has to be closed for the synchronising time-delay mechanism No. 30, as this device is only called into operation while the starting-up relay mechanism No. 1 is working and the motor circuit is then already made.

The voltage conditions on the track in the neighbourhood of the substations will, of course, determine the load which the machine will pick up when switched in. The starting-up relay No. 1 is therefore set to operate only at a voltage which will ensure an economical load. So long as the voltage exceeds this amount, the contacts of No. 1 relay remain open, but when the voltage falls to the predetermined figure the armature is released and the contacts of the relay are closed. The relay, like all others employed in connection with the Peebles-Reyrolle automatic control, is strong and substantial in design, and to obtain the sensitiveness required a separate lifting coil is fitted. In series with the starting-up relay contacts are the lock-out contacts for the starting-up and the underload relays, the time-switch No. 45 and various other devices. The circuit is fed from the 110-volt alternating-current bus-bar, and if all the various auxiliary switches are in their normally closed positions, current will be supplied to the time-delay motor and the operating coil of No. 1 clutch.

With reference to the time-switch No. 45, which switches out the station during predetermined hours, this is fitted with a 14-day clock which is wound up at each weekly or fortnightly inspection of the substation. The times of switching in and out are adjustable, and a special adjustment allows of different hours of working on Sundays. It should be noted that when the time-switch "switches-out" each evening, the operation does not shut down and lock out the substation if the latter is carrying any load. It only controls the starting-up circuit, and the plant will continue to run until shut down by the underload relay No. 37; the substation would then be locked out until the time switch closed again the following morning.

It would take too long to describe in detail the whole of the operations performed automatically by the apparatus and the way in which the various details respond one after another to the requirements of any circumstances. We will therefore confine ourselves to the actual starting and switching in of the motor converter, commencing from the moment of the automatic closing of the main oil-immersed circuit breaker, No. 5 on Fig. 3. When this closes the auxiliary switches which effected its closing are transferred to their running positions. The E.H.T. supply being directly connected to the stator windings by the closing of the main switch, the rotor, of course commences to revolve. The rotor, which, of course, only carries induced low-tension currents, is wound with twelve phases, but only three of these phases are used for running up the machine. The ends of these windings are brought out to three sliprings, the brushes on which are connected to a fixed external three-phase star connected non-inductive starting resistance. The three slip-ring brushes and the ends of the remaining nine phases are brought to 12 contacts which are short-circuited after the machine is synchronised by the motor- (or hand-) operated short-circuiting gear. The other ends of the twelve phases are permanently connected to the D.C. armature winding. The machine is thus started as an ordinary slip-ring induction motor.

As the speed of the rotor increases, the D.C. end, which is self-exciting and disconnected from the bus-bars, builds up its field. When the machine approaches synchronous speed the E.M.F.'s in the rotor and in the armature will alternately be in opposition and in phase, and consequently the current flowing in the starting resistance will be large and small alternately, thus causing the needle of a synchronising voltmeter across the starting resistance to oscillate.

In order to enable the machine to be brought up to speed without taking excessive current from the supply mains a fixed proportion of the shunt regulator resistance is kept in circuit during the operations of starting and synchronising. It is possible to adjust the starting resistance and the shunt regulator so that neither of these requires regulation during starting-up operations. This, indeed, is done before the machine leaves the makers' works, and tappings are taken from fixed stops on shunt regulator No. 8 to the rotor short-circuiting mechanism No. 34, which, when closed on contact No. 9 R short-circuits that particular section of the regulator resistance after the machine is synchronised. The machine now runs up to speed and as the D.C. voltage builds up, the operating coil of polarity relay No. 33 is energised from the machine D.C. control bus-bar. If the machine is building up with the correct polarity, relay No. 33 will close when the pressure reaches 350 volts.

These relay contacts having closed the circuit through choke-coil relay No. 7 is completed. The choke coil itself is inserted across two of the rotor phases, and assists in making the machine self-synchronising. The relay No. 7 has two operating coils and is set to close its contacts when the D.C. voltage rises to 440 volts. When these contacts are closed, the circuit to the operating coil of choke-coil contactor No. 17 is completed and the choke coil is inserted. Both these devices are operated from the D.C. machine voltage, and the returns as in the case of the polarity relay No. 33 are made through an auxiliary switch on the rotor short-circuiting mechanism. When the choke-coil contactor No. 17 closes, its auxiliary switch a is opened and b is closed. The former of these breaks the lifting coil circuit of choke coil relay No. 7, and this relay will now open its contacts should the D.C. voltage fail.

So long as the choke coil is held in circuit it continues to pull the machine into synchronism. The period of operation for a 500 kw. machine is usually from 15 to 20 seconds, during which time the diminishing voltage fluctuations across the starting resistance are followed by the synchronising relay No. 30. As the choke-coil pulls the machine into synchronism the frequency of the oscillation of the voltage across the starting resistance diminishes, until finally the voltage falls to zero and remains there so long as the machine remains in synchronism. The setting of the time delay mechanism previously mentioned is so adjusted that it exceeds the slowest period of the oscillating voltage across the relay, and thus ensures as far as possible that the voltage is steady at zero and that the machine is held in synchronism. The time delay mechanism completes the circuits for the slip-ring short-circuiting contactor No. 31 and the rotor short-circuiting motor relay No. 32.

The first movement of the rotor short-circuiting mechanism operates auxiliary switch 1 of No. 34, and the original feed to the master control circuit No. 3 is broken. This is necessary in order to ensure that if the plant is shut down for any reason while the rotor short-circuiting mechanism is being operated, the starting up circuit will be permanently interrupted. This is to prevent the danger of closing the main oil circuit breaker No. 5 with the rotor partially short-circuited. The operation of short-circuiting the rotor takes about one second, and when the contacts are right home the remainder of the auxiliary switches are transferred to their running contacts.

The machine having been run up to speed and the rotor coils short-circuited, it has next to get itself on load. To prevent the machine being closed on a fault or a heavy overload the discriminating relay No. 19 is provided. This is adjustable, and may be set so that if the load exceeds some predetermined figure, varying from 100 per cent. to 200 per cent. of the normal capacity of the machine, the latter will not be put on to the bars. Assuming that the load is not excessive, the relay No. 19 will close its contacts and will complete a circuit through the closing coil of the high-speed D.C. circuit breaker, thus switching the machine on to the load. The operating coils of relay No. 19 are then de-energised, the contacts are opened and the closing coil contactor No. 20 de-energised in turn. This de-energises the circuit-breaker closing coil itself, so that the closing circuits are completely dead and the breaker is held in only by its own holding coils.

We need not attempt to describe the automatic operations involved in shutting down or in the response of the apparatus to the innumerable conditions and combinations of circumstances with which it may be faced. It is sufficient to say that every possible event seems to have been foreseen, and the mechanism designed to deal with it in the most direct and simple way, taking step after step in proper sequence just as if directed by the brain of an infallible and unemotionable operator. All the thinking has, indeed, been done beforehand, and correct operation is inevitable so long as the plant suffers from no mechanical or electrical derangement. In such an event it does all that inanimate machinery can be expected to do, namely, to protect itself automatically from injury by shutting down, simultaneously notifying the central station that it has done so.

All electrical and mechanical details have been designed with a view to absolute reliability of operation without supervision, for they have to perform their duties unerringly time after time in the complete absence of attention of any kind. Amongst the troubles which are always liable to occur in traction substations are flash-overs on the commutators of the direct-current generators, caused by short-circuits happening on the system. The effect of the heavy short-circuit current is to produce a conducting vapour on the commutator which allows a flash-over to take place between the brushes. Experiments show that the quantity of this conducting vapour is increased both by the magnitude of the short-circuit current and by its duration. It is therefore highly advisable to reduce and extinguish the short-circuit current in the least possible time by means of high-speed switching devices.

Messrs. A. Reyrolle and Co., Limited, have met the conditions by designing a combined low and high-speed circuit breaker of the reactance type, the essential feature of which are illustrated diagrammatically in Figs. 4 to 6, on the opposite page. The circuit-breaker forms a complete metal-clad unit, combining the functions of an ordinary free-handle breaker with those of a high-speed breaker under fault conditions. On account of the special arrangements of the contacts and of the moving parts, no tripping mechanism similar to that of an ordinary breaker is employed. In order to reduce the rate of increase of the short-circuit current, reactance is automatically introduced into the circuit which allows the mechanical parts to accelerate and open the breaker contacts before the current has reached its maximum value. Upon short-circuit the voltage rapidly drops almost to zero, and this fact is used to release magnetically an armature which normally holds the contacts closed, so providing an instantaneous release in place of the usual slower-acting tripping mechanism. The rapidly rising short-circuit current is utilised to exert a magnetic pull on the armature, causing the breaker contacts to open. The opening force is proportional to the

square of the short-circuit current; thus, a heavy short-circuit brings about an extremely rapid opening. The series coils, moreover, which provide this opening force also create a powerful magnetic field, causing instantaneous rupture of the arc. It will therefore be seen that the speed of operation is a function of the intensity of the short-circuit, both the rapid rise of current and the simultaneous rapid fall of voltage being utilised to effect the desired result.

Referring to Fig. 6, which shows the breaker closed, it will be seen that the armature A is held down by a magnet B, excited by a holding coil connected across the terminals of the machine. This armature is connected by a vertical link and lever to the high-speed contact C. Springs tend to open this contact and to raise the armature from the magnet pole beneath it. The series coils D are connected in series with the main contacts, and tend to raise the armature and open the breaker, as shown in Fig. 4. When a short-circuit occurs this series coil overcomes the holding coil, which, as already explained, is subject to practically zero voltage under short-circuit conditions, and the contact arm C opens at very high speed. In the

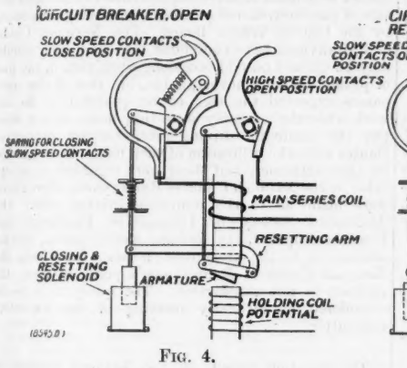


FIG. 4.

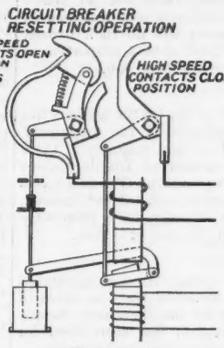


FIG. 5.

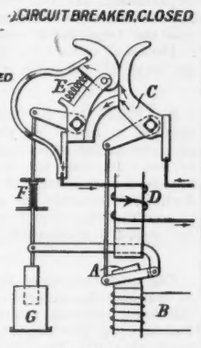


FIG. 6.

closed position this contact arm makes contact with the slow-speed arm E, which is kept in the position shown by the spring F.

Fig. 5 illustrates the first movement which takes place when the circuit-breaker is reclosed (either automatically or otherwise). The closing magnet G has been energised and performs two functions simultaneously—firstly, the opening of the slow-speed contacts from the position shown in Fig. 6; and, secondly, the depression of the horizontal lever which in turn pushes the armature A down on to its holding magnet B. In this way the high-speed contacts and armature are reset for operation, but it should be noted that the circuit has not been completed owing to the backward position of the slow-speed contacts. Upon the closing magnet being de-energised the spring F closes the slow-speed contacts and completes the circuit as shown in Fig. 6.

The construction illustrated has the advantage that the high-speed contacts can be made comparatively light, as the necessary flexible brush and rolling sparking contact are embodied in the slow-speed portion. The closing magnet G may be energised by means of a hand-controlled switch, or it may work, as it does in the case of the automatic substation, in conjunction with a load discriminating relay so that the breaker will not close with a short circuit on the system, but only under pre-determined conditions of load. The behaviour of the high-speed circuit breaker in practice as compared with that of an ordinary breaker is illustrated by the curves reproduced in Fig. 7. It will be seen from curve "A" that with the ordinary breaker and no reactance in circuit the D.C. current on a short circuit reaches about 17 times its normal full load value in about $\frac{1}{100}$ of a second. Curve "B" shows the current in a short-circuit on the same 500-kw. machine under the control of a high-speed circuit breaker. The current grows comparatively slowly, due to the reactance of the breaker, and its maximum value rises only to about 8,700 amperes as compared with the 17,000 amperes or so which would flow in a short-circuit on the same machine opened by an ordinary breaker. Oscillograph tests show that when a short-circuit is dealt with by a breaker of the ordinary type, the commutator of the machine has to deal with 10 to 12 times the thermal energy that would be required in the case of a high-speed breaker of the type described. The bearing of this fact upon the freedom from flash-overs which is secured by the new type of breaker is obvious.

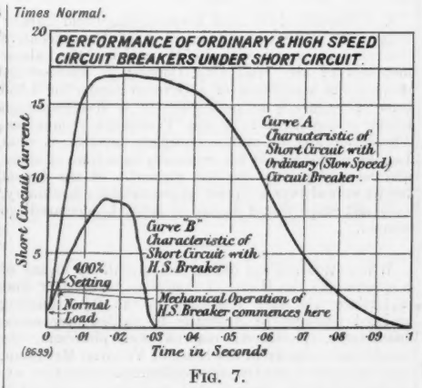

Times Normal.
PERFORMANCE OF ORDINARY & HIGH SPEED CIRCUIT BREAKERS UNDER SHORT CIRCUIT.
Short Circuit Current
Curve A Characteristic of Short Circuit with Ordinary (Slow Speed) Circuit Breaker.
Curve B Characteristic of Short Circuit with H.S. Breaker
400% Setting
Normal Load
Mechanical Operation of H.S. Breaker commences here
Time in Seconds
(8539)

FIG. 7.

From the description which we have been able to give of the equipment of the Peebles-Reyrolles automatic substation, it will be seen that the makers have succeeded in producing a plant which will come automatically into service whenever the load on the system demands it, and will equally automatically shut down when its services are no longer required. It will deal, apparently, with every condition that may arise in an appropriate way, and carry out quite complex operations with certainty whenever the need arises.

Mechanism has the advantage over the human operator that it can never be flustered in an emergency, but will act in a predetermined manner without haste, delay or excitement whenever the circumstances demand its intervention. So long as it is reliable mechanically, and is designed to act appropriately under any circumstances that may arise, either controlling the behaviour of the plant or shutting it down altogether, if that is the best thing to do, it has advantages over the most skilled operator in that it is immune from making mistakes. The expense of keeping an operator in constant attendance on the machinery is entirely avoided, and if the wages saving on this account is capitalised it will overwhelmingly repay the slight extra cost of rendering a substation completely automatic. All those who are interested in automatic operation can be recommended to visit the stand of Messrs. Bruce, Peebles & Co., Limited, at the British Empire Exhibition, where the Peebles-Reyrolle gear is shown in operation, and the arrangements are such that its response to any artificially produced conditions can be observed and studied.

GLASS TECHNOLOGY.—A handbook of Experimental Researches and Reports has just been published by the Department of Glass Technology of Sheffield University. The book is a compilation of papers previously read, which deal with various problems in glass manufacture with which we dealt at the time of their original presentation.

THE LATE MR. ROBERT CRIGHTON.

WE regret to announce the death of Mr. Robert Crighton, the deputy-chairman of Messrs. Harland and Wolff, Limited, which occurred in his 70th year, on Wednesday, August 27. Mr. Crighton was born in Auchtermuchty, Fife, but went to Birkenhead to receive his engineering training at the Britannia Engine Works, after which he became a draughtsman in the office of Messrs. Heidel and Demblow, the consulting engineers and naval architects. In 1878, he entered the service of the Red Star Line, and five years later became chief superintendent of hulls and machinery. He joined Messrs. Harland and Wolff as manager of their Southampton Works in 1907, and continued to hold that position after he accepted the management of the Liverpool repair works of the firm. Later he became a managing director and deputy chairman and took charge of all the repairing establishments of the company. He was a director of Messrs. Burmeister and Wain, Limited, the London and Glasgow Shipbuilding Company, Limited, Messrs. Caird and Co., Limited, Messrs. David Colville and Sons, Limited, Messrs. Archibald Russell, Limited, the Ardrossan Harbour Company and the Ocean Transport Company, Limited. He was a member of the Institution of Mechanical Engineers and the Institution of Naval Architects.

THE LATE MR. W. M. MOYLAN.

WE regret to note the death at sea on July 28 of Mr. William Morgan Moylan, of 7, Vicarage-gate, Kensington. He was returning home from India, where he had devoted a large part of his life to railway construction.

Mr. Moylan was born in 1861 and was educated at Stoneyhurst and obtained his practical engineering training in the works of Messrs. Hick, Hargreaves and Co., Limited, Soho Iron Works, Bolton, and afterwards spent two years at sea in the engine room of ss. Shannon. From 1885 to 1888 he was engaged in the office of the Inspector-in-Chief of Steam Boilers and Prime Movers of Bombay Presidency. His next undertaking was the transport of the heavy steam machinery for a factory at Parli, Hyderabad, a distance of 150 miles across difficult country, and he carried out its complete erection.

He later drove two of the tunnels, under the direction of Colonel Beaumont, R.E., in the Tausa Tunnel contract and afterwards devoted himself largely to this class of work. He was manager of works for Messrs. Forster and Co. on the construction of the Gorlkora tunnel on the Bengal-Nagpur Railway. From 1893 to 1898 he was engaged on the cutting of tunnels for the Assam-Bengal Railway. Later, as a member of the firm of Messrs. Moylan and Scott, he was engaged on the construction of the Gya Katrasgarh Railway, now called the Grand Chard, East Indian Railway, and of the Nagda-Muttra State Railway, including a bridge over the Kalascied River. In the last 15 years he continued his railway constructional work on part of the Great Indian Peninsula Railway and on the Southern Shan State Railway, and was engineer and manager of works on the contract for the construction of the Kassara Tunnel.

Mr. Moylan was elected an associate member of the Institution of Civil Engineers in 1902 and transferred to the class of member in 1914.

LABOUR NOTES.

IN the course of his presidential address to the Trades Union Congress, at Hull, on September 2, Mr. A. A. Purcell, M.P., described the report of the Committee which dealt with labour supply and building material for the programme of 2,500,000 houses in 15 years as "an historical industrial document, taking stock of the needs and requirements of the community and forming a complete census of the capacity of the building industry, with a practical, workmanlike survey of the changes in organisation, equipment and power needed to get the required results." He saw no reason, he said, why a similar stocktaking should not be undertaken, and an account rendered, by each industry. In his view, this was really the first step that had been taken in the direction of a general reorganisation of industry, leading to control of such a type as would ensure that the standard of living, working conditions, and hours of labour should be such as to enable each industry to be fully manned with those who were capable of employment therein, by training, habit and personal preference.

After reviewing conditions of labour at home, Mr. Purcell went on to say that "the dole" was no cure for the clear million of workers still remaining unemployed. Relief work—digging holes and filling

them up again—was not, he said, a remedy. Emigration offered no way out. Additional training in other industries, and every such method would not cut out this cancer in our social system. Side by side with this problem there festered a mass of people crowded together in the vilest slums, and in sharp contrast they saw the class engaged in exploiting and profiteering taking every mean and selfish advantage of the necessities of the working people. "Our great and glorious task is," Mr. Purcell declared, "to deal with the problem of poverty at its roots, and to solve it by bringing about a more equitable distribution of the wealth produced by the labour of our class."

In its treatment of the National Minority Movement's resolutions, the General Council of the Trades Union Congress acted, of course, with strict constitutional propriety. It can only give effect to decisions arrived at by Congress on resolutions sent in by trade union organisations affiliated to Congress, and the National Minority Movement does not yet belong to that category. If the National Minority Movement had really desired to have its proposals discussed by Congress, and had not been bent merely on propaganda, it could have instructed some of its adherents who are duly accredited delegates formally to move the resolutions. Several of the subjects covered by the resolutions were, as a matter of fact, on the Congress agenda. The "programme of action," to which the Congress were invited to give effect, called for, amongst other non-political items, a wages increase of 1*l.* per week with a minimum wage of 4*l.* per week; a 44 hours' working week and the abolition of overtime; the formation of Workshop Committees whose members should be guaranteed against victimisation; affiliation of the Unemployed Workers' Committee and the Trades Councils to the Trades Union Congress and representation on the General Council; the creation of a General Council with full powers to direct the activities of the unions and under obligation to the Trades Union Congress to use that power; workers' control of industry; the repeal of all anti-Labour laws; and the unity of the international trade union movement.

At the meeting of the Trades Union Congress on Wednesday, September 3, a discussion was held on what has been termed the "Industrial Workers' Charter." This consists of a statement of the principles which the Congress has adopted from year to year. As supplemented by amendments this "Charter" was adopted. It calls for the nationalisation of land, mines, minerals and railways, the extension of State and municipal enterprise for the provision of social necessities and services, participation of the workers in the control and management of industry, a 44-hour week, a legal minimum wage, adequate maintenance of the unemployed, educational and other training, compensation for accidents and provision for workers at the age of 60 years and for widows and orphans. A resolution which was passed pledged the Congress to a vigorous campaign throughout the country in support of the objects of the "Charter."

At its congress in Vienna, the Textile Workers' International took, in effect, the same course on the question of admitting the Russians to affiliation as the Metalworkers' International. But while the representatives of the Metalworkers deferred further consideration of the matter until a future meeting, the representatives of the Textile Workers passed the following resolution unanimously and without debate: "The Russian textile workers can only be admitted to the Textile Workers' International when an agreement between the International Federation of Trade Unions and the Red Trade Union International has been arrived at, and when the adhesion of the Red International to the Amsterdam International has taken place."

The reports of the delegates to the Textile Workers' International on the subject of the eight hours' day were to much the same effect as those of the delegates to the Metalworkers' International. Herr Lang stated that in Germany the eight hours' day had been partially lost, but the General Federation of Trade Unions was doing everything possible to regain it. Herr Schwarz said that the main task of Hungarian workers was to regain the eight hours' day. In most Hungarian factories at present more than eight hours a day were, he stated, being worked. Signor Galli reported that in Italy the eight hours' day law had become a dead letter, and Mr. Voogsherd that in Holland the eight hours' day existed only nominally. In a struggle that had lasted over eight months, Mr. Voogsherd added, the eight hours' day had been lost owing to the action of the Christian Trade Unions; but Dutch workers refused to despair and were continuing the fight. The Congress eventually passed a resolution expressing the opinion that it was the duty of all the national organisations, in collaboration with the other trade unions in their countries, to press for the immediate ratification of the Washington Eight Hours' Day Convention; that the workers should have the full Saturday afternoon; and that the shortening of hours should be simultaneous in all countries. It also contained a formal declaration that the workers were opposed to every system of shifts in the textile industry and emphatically refused to do night work.

Mr. Arthur Harrison, district organiser at Woolwich of the National Union of General and Municipal Workers, has received a letter from the Financial Secretary to the War Office, dealing with the "discharges which will be necessary from the Army Ordnance Department at Woolwich, arising from the evacuation of stores from the Dockyard." In it, Mr. Lawson stated that arrangements are in hand by which as many men from the A.O.D. as possible will (having regard to the claims of ex-employees of the establishments concerned who may be asking for re-employment) be placed in the Ordnance Factories and the Inspection Department, if suitable vacancies occur. The letter continued: "Over 60 men who were likely to have to leave the Ordnance Department in the near future have already been fitted in to the Inspection Department. At the moment, there are no others due for immediate discharge, but you may rest assured that the Department concerned will do their utmost in the men's interests to fit them in to a proportion of any available vacancies when the time comes."

It is stated that the ballot of the textile workers has resulted in favour of acceptance of the employers' proposal on the wages question by a majority of three to one. In June the Association of Textile Unions applied for an increase of 10 per cent. The employers declined to concede the demand, and offered, instead, to continue the current rate of wages for a year without regard to fluctuations in the cost of cotton.

The next meeting of the special tribunal appointed to consider the differences between the two sides of the Joint Industrial Council for the Electricity Supply Industry on the wages question has been fixed for September 10. The proceedings are to be public.

At a meeting of the Hull Trades Council and Labour Party, Mr. Cavanagh, a member of the executive council, was severely critical of the action of the Labour members of the Hull City Council in successfully moving the acceptance of a German tender for 1,555 tons of tramrails in preference to a Middlesbrough tender recommended by the Tramways Committee. The action was, he said, a complete reversal of what Labour policy should be, especially in a time of stress and unemployment like the present. If the lowest tender were always accepted, all contracts for machinery, rails and ships would sooner or later, he declared, go abroad.

When attention was drawn last month by means of a question in the House of Commons to the fact that advertisements were appearing in the Press offering assisted passages to Australia to skilled carpenters, bricklayers, plasterers, masons and plumbers, for employment chiefly in the State of Victoria, Mr. Lunn, the chairman of the Oversea Settlement Committee, explained that the Government had not considered it desirable to interfere. Since then a telegram has been received from Melbourne instructing the Director of Migration and Settlement to cancel all existing applications under the Victorian requisition, provided no hardship is involved. It is understood that the total number originally asked for was 800, and that 146 men, with their families, have actually sailed.

Following a practice which has found considerable favour on the other side of the Atlantic, the wives of members of the Associated Society of Locomotive Engineers and Firemen are to be enrolled in an auxiliary organisation to be known as the Associated Society of Locomotive Engineers and Firemen—Women's Society. Addressing a conference called to consider the matter, Mr. Bromley stated that during the strike in January last, the womenfolk of members had been of immense help to them, and as a result it was decided in some places to set up organisations on the lines of the Co-operative Women's Guilds. These isolated organisations had now got together with the object of forming an auxiliary to the parent Society. He personally believed, he went on to say, that the women's organisation would be a very powerful adjunct. In times of struggle with the employers an understanding body of women could be of tremendous assistance, whereas when the womenfolk were ignorant of the facts they might become a real menace to the cause of their husbands and lovers. The expectation is that the Society will have a membership of 800 to begin with.

According to the *Board of Trade Journal* skilled workers belonging to the metal and engineering trades emigrated to non-European countries in much larger numbers in 1923 than in either of the two immediately preceding years. In 1921 the total was 8,016, and in 1922, 10,536; the figure for 1923 was 24,724. The loss of skilled workers of all kinds to the United States is officially described as "disturbing." The total for last year was 28,827, and, of these men, 14,274 were metal and engineering workers as compared with 3,956 such emigrants in 1922 and 2,047 in 1921. That the whole of these skilled metal-workers will be permanently lost to British industry is, however, in our opinion, improbable. Men went abroad because no work was procurable here, but with the slight revival of engineering that has taken place some are already returning. Commander Craven recently stated that a number who went abroad when the depression was deepest at Barrow-in-Furness had now returned to the employment of Vickers Limited, there.

The extent to which men other than qualified drivers should be utilised to move engines under steam, and the rate of pay they should receive, is now being considered by the Central Wages Board. The National Union of Railwaymen have contended that such men should only be utilised on odd occasions when men in the line of promotion were not available, but that if the companies expected the men to be qualified to do the work when the necessity arose they must, at any rate, pay the minimum driving rate. Certain protective clauses as to the utilisation of such men were suggested by the companies, and these were regarded as acceptable by the National Union of Railwaymen, if provision were made as to the minimum driving rate. The Associated Society of Locomotive Engineers and Firemen proposed, the *Railway Review* states, certain alterations to the protective clauses; but, from the National Union of Railwaymen's point of view, the position is not satisfactory. The question is to be considered at an early meeting of the executive committee.

The question raised by the National Council of Port Labour Employers in their letter to the Transport Workers' Union is not unreasonably regarded as important by employers generally. The opinion was expressed in this communication that the placing of an embargo at the ports on the handling of produce intended for Covent Garden was a breach of the national agreement between the Transport Workers' Union and the Port Labour Employers. Mr. Bevin has replied to the effect that in the judgment of his executive council there has been no breach of the agreement. Neither in writing nor by implication, he says, has the executive council ever entered into an agreement which prevents the members of the union taking sympathetic action with their fellow-workmen. If the union admitted the principles laid down in the Port Labour Employers' letter it would be possible, Mr. Bevin claims, for the employers in any industry to claim the services of the members of the union under any circumstances to "blackleg" their fellows.

TENDER.—As a consequence of the adoption of a scheme for State Railway electrification in Czecho-Slovakia, a call for tenders has been issued for locomotives and materials for this work. These tenders must be presented by October 21 this year, and British firms are warned that it is essential for them to be represented in Prague. Such firms in a position to supply British materials can obtain further particulars and assistance towards local representation from the Department of Overseas Trade, 35, Old Queen-street, London.

THE KENNINGTON LOOP TUBE EXTENSION.—The work of extending the Hampstead Tube from Charing Cross to Kennington is now proceeding from four different points along the route line and it is hoped to have this important addition to the Underground service ready for traffic by the close of next year. The new line, which will extend over 2 miles, will enable through services of trains to be worked between Morden and Edgware via Charing Cross, a distance of over 20 miles. There will be one intermediate station on the extension, at Waterloo. The task of driving the twin tunnels beneath the bed of the river presents an interesting feature in that the sub-river loop which forms the terminus of the Hampstead Tube at Charing Cross lies right in the course of the new line and will require to be cut through in two places. This operation will be carried out under compressed air after the Charing Cross loop has been abandoned for traffic purposes. Further, at Kennington, besides the junction between the Hampstead and the City and South London lines, a new loop, similar to the one at Charing Cross, will be constructed in order that certain of the south-bound trains of the Hampstead Tube may be reversed here, as is at present done at Charing Cross.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Though there is absence of reliable evidence to support this view, engineering masters are hopeful that the advent of September will mark an improvement in trading conditions, and that the worst features of the last two months will not be repeated. Faint signs are to be discerned of better times in certain sections of the heavy trades. Business in shipbuilding steel and marine castings appears definitely to be on the up-grade, and there are indications that the demand for constructional ironwork may develop as the result of schemes under consideration at home and abroad. Competition for new business in circulation from South America for heavy machinery is exceptionally keen, and from the standpoint of the proportion of orders booked locally, suffers from the ability of Continental producers to offer considerably longer credits than South Yorkshire makers are able to agree to. Mining steel is in request from British collieries that are undertaking development schemes, but business in heavy steel for railway construction has fallen slack, and numerous departments dependent thereon experience difficulty in maintaining even part-time employment. The building trades are expected to call for increased supplies of stove grates, pipes and ironmongery when they recover fully from the effects of the recent dispute. Orders for wire rope and rods are fewer than for many months past. The lighter steel sections are moderately employed, though the bulk of business in engineers' and other tools is confined to quantities sufficient to cover current operations. Revised quotations in raw and semi-finished materials reveal a general weakening of the position from the producers' standpoint. Forge iron is cheaper than for the past eighteen months, but attracts few buyers, and output is being curtailed. Hard basic billets are quoted at 9*l.* 10*s.* per ton, soft basic billets at 8*l.* 5*s.*, West Coast hematites 5*l.* 10*s.*, East Coast hematites 4*l.* 15*s.*, Lincolnshire No. 3 foundry 4*l.* 7*s.* 6*d.*, Lincolnshire forge 4*l.* 5*s.*, Derbyshire No. 3 foundry 4*l.* 7*s.* 6*d.*, Derbyshire forge 4*l.* 5*s.*, bars 13*l.* 10*s.*, and sheets 15*l.*, all delivered at local works. The dispute at the three principal works producing basic steel is unsettled, but with the bulk of furnaces standing idle supplies seem to be sufficient to meet requirements.

South Yorkshire Coal Trade.—Though local coal-owners state that the proposed payment of reparations in coal by Germany to France and Belgium is calculated to throw collieries idle two days a week, current demand from the Continent shows definite expansion, and best steams are firmer at recently revised rates than for several weeks. Cobbles, nuts and best quality slacks retain the improvement reported a week ago. Individual pits have taken advantage of more numerous bookings in house coal to advance prices, though official quotations are nominally unchanged. The coke position remains unaltered, except that sales of gas coke to inland users have slightly improved. Quotations:—Best branch handpicked, 32*s.* to 35*s.*; Barnsley best silkstone, 26*s.* to 28*s.*; Derbyshire best brights, 25*s.* to 27*s.*; Derbyshire best house, 23*s.* to 25*s.*; Derbyshire best large nuts, 21*s.* to 25*s.*; Derbyshire best small nuts, 15*s.* to 17*s.* 6*d.*; Yorkshire hards, 21*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire hards, 21*s.* to 23*s.*; rough slacks, 12*s.* 6*d.* to 15*s.* 6*d.*; nutty slacks, 12*s.* to 14*s.*; smalls, 6*s.* to 8*s.* 6*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Transactions in Cleveland pig iron are few and small, and prospects of material change for the better appear remote. Producers are very reluctant to make price concessions, declaring that current rates are already unremunerative. Values, however, continue on the downward curve, and it is understood that recognised market rates can be readily shaded. No. 1 is obtainable at 88*s.* though 88*s.* 6*d* is asked; No. 3 g.m.b. is on sale at 83*s.*; No. 4 foundry is 82*s.*, and No. 4 forge, 81*s.*

Hematite.—Supply of East Coast hematite is still a good deal in excess of current needs notwithstanding further curtailment of output by the blowing out of a furnace at the works of Messrs. Gjers, Mills, which lays the whole five of the firm's furnaces idle. No. 1 hematite is offered freely at 92*s.* 6*d.* and Nos. 1, 2 and 3 are on sale at 92*s.*

Furnaces in Operation.—Of the 113 blastfurnaces erected on the North East coast, only 42 are now in operation. Of these 12 are making Cleveland pig iron, 14 are producing hematite, and 16 are manufacturing other kinds of iron.

Foreign Ore.—Imported ore is lifeless with market rates based nominally on best rubio at 22*s.* c.i.f. Tees.

Blastfurnace Coke.—Durham blastfurnace coke is very quiet. Good medium qualities are in the neighbourhood of 25*s.* 6*d.* delivered to local consumers.

Imports of Iron and Steel.—The Tees Commissioners' returns issued this week give the iron and steel imports to the River Tees from Holland, Belgium, France, Norway, Sweden, Germany, India and coastwise for the ten months ending August 31, as compared with the same months a year ago, and with the corresponding pre-war period of 1913–14. Pig-iron brought in during the past ten months amounted to 19,542 tons as against 11,094 tons a year ago, and 312 tons in the pre-war period; crude sheet, bars, billets, blooms and slabs unloaded in the past ten months reached 71,111 tons as against 60,351 tons a year ago, and 33,646 tons in the pre-war period; and plates, bars, angles, rails, sheets and joists imported in the past ten months totalled 16,091 tons as against 10,315 tons a year ago, and 19,441 tons in the pre-war period.

Shipments of Iron and Steel.—Total shipments of iron and steel from the Tees during August totalled only 73,955 tons, 29,965 tons being pig iron, 5,130 tons manufactured iron and 47,427 tons steel. Of the pig iron shipped, 11,464 tons went to foreign ports and 18,501 tons went coastwise; of the manufactured iron cleared, 790 tons went abroad and 4,340 tons went coastwise, and of the steel despatched, 39,100 tons went overseas and 8,327 tons went coastwise. Scotland was by far the largest customer for pig iron, taking 15,007 tons, whilst Belgium received 3,413 tons; Wales, 2,195 tons; Germany, 1,205 tons; and America, 1,080 tons. The Straits Settlements, with an import of 300 tons, were the biggest buyers of manufactured iron. Principal steel importers were:—India, 9,922 tons; the Argentine, 3,697 tons; Victoria, 2,770 tons; Chile, 2,306 tons; and China, 2,115 tons.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The depressed state which has existed in the Scottish steel trade for some time still prevails, and the outlook continues somewhat uncertain. It is true that one or two concerns are rather better off for work, having a close connection with shipyards which have a few orders on hand, but the majority can only manage to keep a portion of the plant in operation. Shipbuilding material on the whole has experienced just a shade better demand of late, but actually nothing very heavy, and there seems little prospect of any decided improvement in the immediate future. Structural engineers have a fair amount of work on order, although the consumption of material is a long way short of what is expected at this time of the year. The general export trade is poor and inquiries are far from satisfactory. The black sheet makers continue to do well, except in the heavier gauges, which are very slow of sale. The recent demand for galvanised sheets for abroad means steady running of plant for some months to come. Prices are officially unchanged, but most of the steel producers would willingly enter into negotiations for any lot of good tonnage. To-day's market quotations are as follows: boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, $\frac{7}{8}$ in. to $\frac{1}{4}$ in., 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—No improvement of any kind can be reported in the West of Scotland malleable iron trade. Many things are advanced as the cause of the present lowly state of the industry, but until the markets of the world settle down considerably little change can be expected. Work is only being carried on from day to day, and the great uncertainty about the morrow means much anxiety. The re-rolled steel branches are also only being kept moving. The price quoted for "Crown" bars is still 12*l.* 10*s.* per ton, d/d Glasgow stations.

Scottish Pig-Iron Trade.—The Scottish pig-iron trade continues dull and lifeless. Buyers are few and far between and not only is the home demand very poor but export sales are about the minimum at present. The output continues on the small side, and stocks are varying very little. Prices are weak, but the following may be taken as the current quotations: hematite, 4*l.* 16*s.* 3*d.* per ton, delivered at the steel works; foundry iron, No. 1, 4*l.* 18*s.* 9*d.* per ton, and No. 3, 4*l.* 13*s.* 9*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, August 30, were small and only amounted to 461 tons. Of the total, 370 tons went overseas and 91 tons coastwise. For the corresponding week of last year the figures were 914 tons foreign and 94 tons coastwise, making a total shipment of 1,008 tons.

Scottish Shipbuilding.—The state of the shipbuilding industry in Scotland is not very healthy at present, and although the number of vessels launched in recent months has been very good, there are not enough orders on hand for new tonnage to fill up the stocks again. During the past month, 14 contracts were reported, 8 for the Clyde, and 3 each for Aberdeen and Montrose, but few of these are of large tonnage—the largest being an Anchor liner of 9,600 tons. Unless a decided improvement takes place in the number of new contracts at no distant date, the outlook will become very serious, and from the employment point of view in particular. The output for the past month was as follows:—

	Vessels.	Tons.
The Clyde	15	48,683
The Forth	1	2,775
The Tay	—	—
The Dee and Moray Firth...	2	124
Total	18	51,582

The Clyde output was over the average monthly total for the year to date, and brings the year's figures up to 148 vessels of 330,885 tons, which are the highest for the corresponding period since 1920. The above total compares favourably with the first eight months of last year, when 72 vessels of 148,276 tons were launched, but it is the future, as already stated, which gives us the greatest concern. Shipowners are not inclined to enter the market yet, and until they can see the prospect of remunerative freights they are not likely to give out contracts for tonnage at the high costs prevailing.

NOTICES OF MEETINGS.

THE INSTITUTE OF BRITISH FOUNDRYMEN: LANCASHIRE BRANCH.—Saturday, September 6, at 3.15 p.m. Visit to the Grappenhall Works of the Richmond Gas Stove and Meter Company, Limited, near Warrington.

THE INSTITUTE OF METALS.—Autumn Meeting.—Monday, September 8, to Thursday, September 11, at the Institution of Mechanical Engineers, Storey's-gate, S.W.1. Monday, September 8, at 8 p.m., Third Annual Autumn Lecture: "Recent Developments in Non-Ferrous Metallurgy in the United States, with Special Reference to Nickel and Aluminium-Bronze," by Mr. W. M. Corse. Tuesday, September 9, and Wednesday, September 10, at 10 a.m. The following papers will be read and discussed:—(1) Mr. Robert J. Anderson and Mr. Everett G. Fahlman: "A Method for Measuring Internal Stress in Brass Tubes"; (2) Mr. D. H. Andrews and Professor John Johnston: "The Application of the Ideal Solubility Curve to the Interpretation of Equilibrium Diagrams in Metal Systems"; (3) Dr. Guy D. Bengough and Mr. R. May: "Seventh Report to the Corrosion Research Committee of the Institute of Metals"; (4) Mr. E. H. Dix, Jun., and Lieut. A. J. Lyon: "Comparative Results on Copper-Silicon-Aluminium and Other Aluminium Alloys as Obtained on Separately Cast Specimens and Specimens cut from a Crankcase Casting"; (5) Mr. D. M. Fairlie and Mr. G. B. Brook: "The Determination of Sodium in Aluminium"; (6) Mr. R. Genders: "The Extrusion of Brass Rod by the Inverted Process"; (7) Dr. D. Hanson and Miss Grace W. Ford: "Investigation of the Effects of Impurities on Copper: Part II.—The Effect of Iron on Copper"; (8) Mr. Douglas H. Ingall: "The Relationship between Tensile Strength, Temperature and Cold-Work in Some Pure Metals and Single-Solid Solutions"; (9) Dr. H. Moore: "On the Effect of Progressive Cold-Rolling on the Brinell Hardness of Copper"; (10) Sir Thomas K. Rose and Mr. J. H. Watson: "Experiments on the Working of Nickel for Coinage"; (11) Mr. Francis W. Rowe: "Some Experiments on the Effect of Casting Temperature and Heat-Treatment on the Physical Properties of a High-Tin Bronze"; (12) Mr. Francis W. Rowe: "Some Experiments on the Influence of Casting Temperature and Mass on the Physical Properties of Admiralty Gun-Metal"; (13) Mr. Tomojiro Tanabe: "Studies in the Aluminium-Zinc System"; (14) Mr. T. Henry Turner and Mr. W. E. Ballard: "Metal Spraying and Sprayed Metal." Tuesday, September 9, at 1 p.m., Luncheon in the Large Banqueting Hall, Connaught Rooms, Great Queen-street, W.C. 2. At 2.45 p.m. visit to the British Empire Exhibition, Wembley. Wednesday, September 10, at 2 p.m., Visits to various works. At 7.50 p.m. for 8 p.m., Reception at the National Physical Laboratory, Teddington. Thursday, September 11, at 9 a.m., Trip to Windsor.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, September 9, at 6.30 p.m., at 85/88, The Minories, Tower Hill, E.1. "The Measurement of Pressure," by Mr. J. L. Hodgson, B.Sc.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Depression continues in the Welsh coal trade, and notices have been tendered to more miners, as owners cannot keep their pits going at a loss. A further endeavour has been made to conclude a local district agreement, embodying the terms of the national wages agreement, but no settlement has yet been reached. The miners are pressing for increased rates for bunkers, but the owners declare that the present financial state of the industry would not permit of anything further being done. Meanwhile the certificate of the joint accountants of the proceeds and costs certifies the wages as payable in September at 20·72 per cent. on the 1915 standard rates, which compares with 24·06 for August, and is 21·50 per cent. below the present minimum, and even 7·50 per cent. below the old minimum. The trading results for May, June and July, the first quarter under the new agreement, show that there was a loss of 198,382*l.*, or 3·98*d.* per ton, on the output of 11,946,373 tons. The proceeds amounted to 11,436,214*l.* and the costs to 11,634,596*l.*, of which wages represented 7,867,820*l.* and "other costs" 3,766,776*l.* In the first three months of this year, the output totalled 12,655,000*l.* and the wages under the old agreement to 7,505,000*l.*, whereas under the new agreement for a lesser quantity of coal, the wages cost, including subsistence and guaranteed wages, amounted to 8,028,000*l.*, an increase of over 500,000*l.* for 710,000 tons less coal. On the coal market available supplies continue excessive, despite the closing down of collieries and frequent temporary stoppages. Best Admiralty large rules steady at 28*s.* to 28*s.* 6*d.*, but all other classes of coal are in ample supply, and prices are dependent on individual circumstances. Best Monmouthshire large coal is not worth more than 25*s.* 6*d.*, and best smalls are easily obtainable at 17*s.* The undertone however is somewhat better, and of late there has been more activity in shipment operations at the docks, though a substantial amount of new business is still needed to improve selling values.

Iron and Steel.—Exports of iron and steel goods last week totalled only 10,340 tons, compared with 15,674 tons in the preceding week. Shipments of tinplates and terneplates amounted to 4,856 tons, compared with 6,299 tons; blackplates and sheets to 2,930 tons against 4,686 tons; galvanised sheets to 1,639 tons, against 3,087 tons; and other iron and steel goods to 915 tons, against 1,602 tons.

THE PEEBLES-REYROLLE AUTOMATIC SUBSTATION; EMPIRE EXHIBITION.

(*For Description, see Page* 323.)

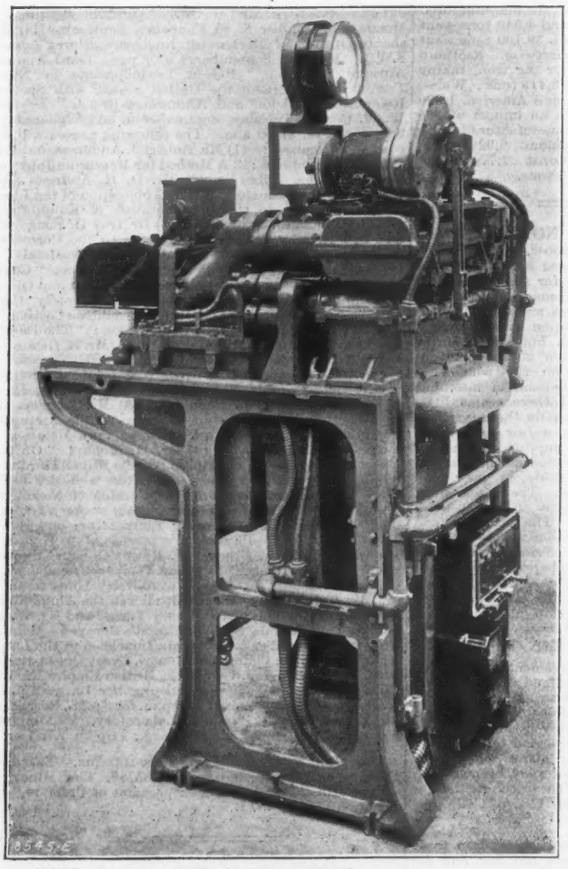


FIG. 8. A.C. METAL-CLAD MOTOR-OPERATED PANEL.

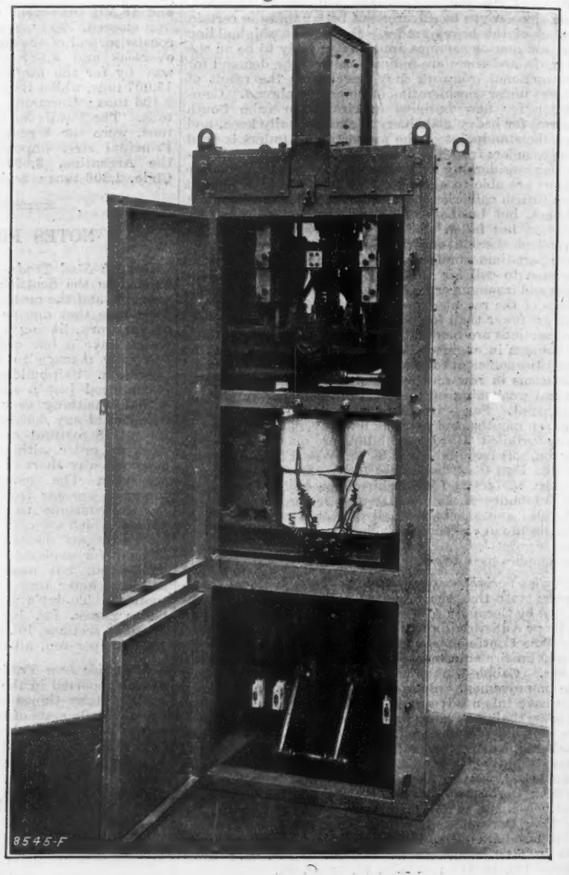


FIG. 10. D.C. MACHINE PANEL, SHOWING INTERIOR.

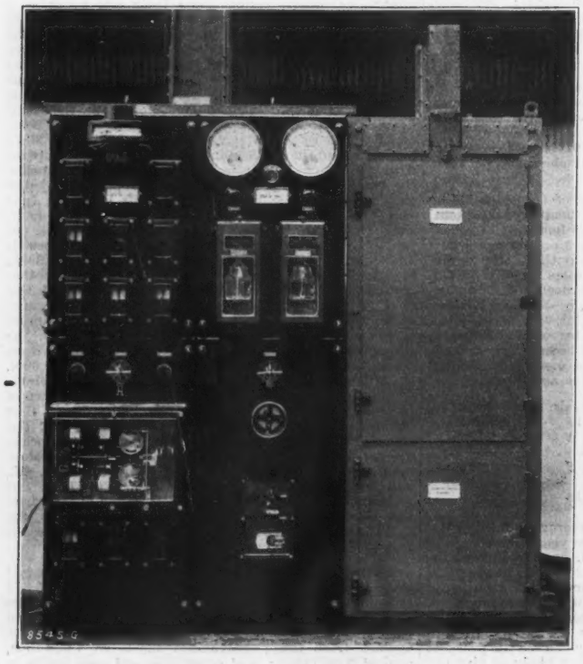


FIG. 9. CONTROL PANELS AND D.C. MACHINE PANEL.

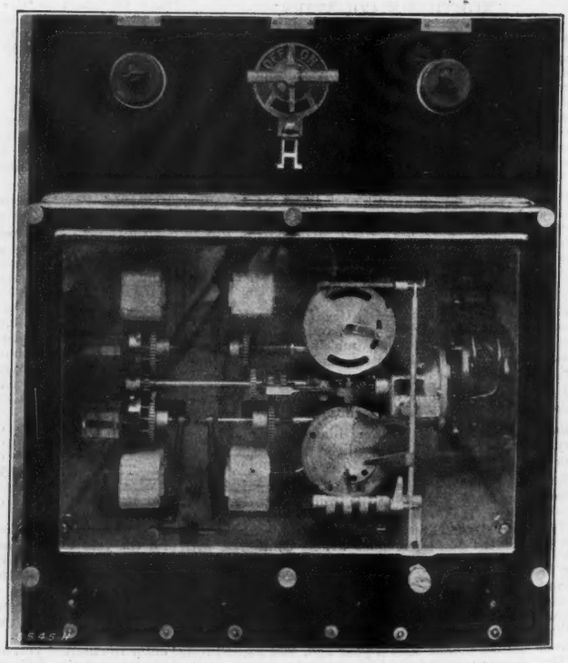


FIG. 11. MULTIPLE TIME DELAY DEVICE ON CONTROL PANEL.

LATHES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

(*For Description, see Page* 310.)

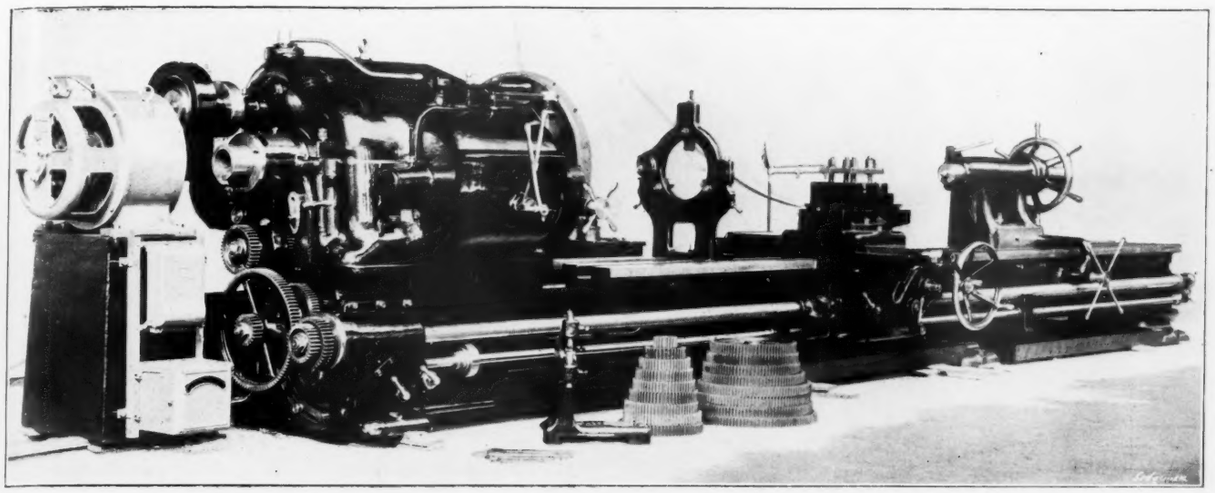


Fig. 2. 18½-In. Centre Sliding, Surfacing and Screw-Cutting Lathe; The Selson Engineering Company, Limited.

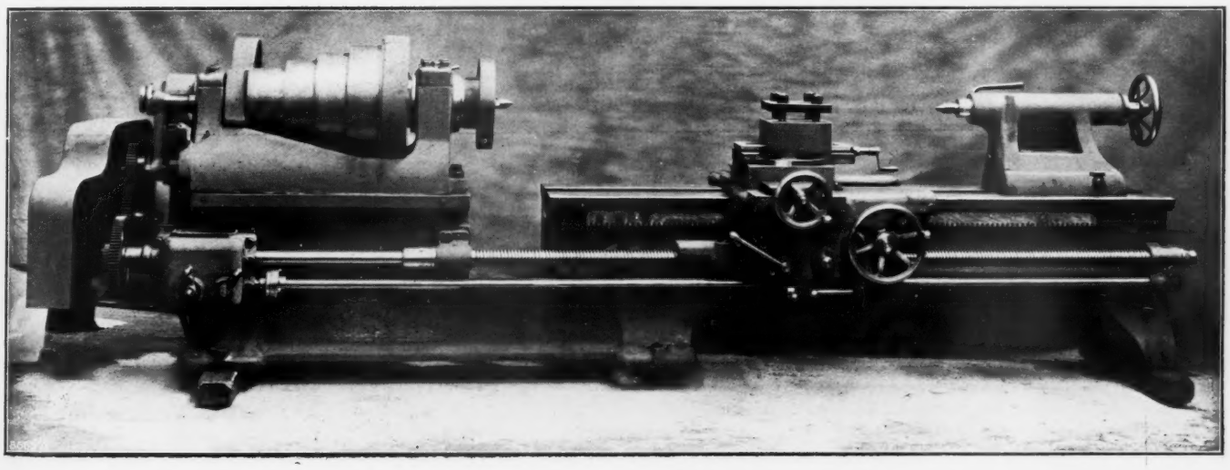


Fig. 3. 13-In. Centre General Purpose Lathe; Messrs C. Redman and Sons, Limited.

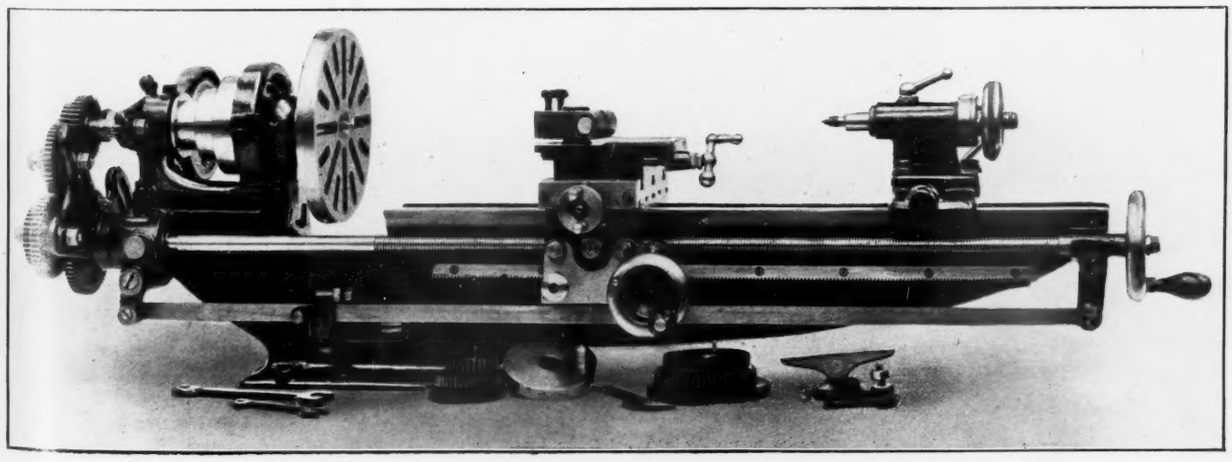


Fig. 4. 3½-In. Centre Long Bed Lathe; Messrs. Drummond Brothers, Limited.

(*To face page* 310.)

VERTICAL TURRET LATHE AND BORING MILL; MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. WEBSTER AND BENNETT, LIMITED, ENGINEERS, COVENTRY.

(*For Description, see Page* 310.)

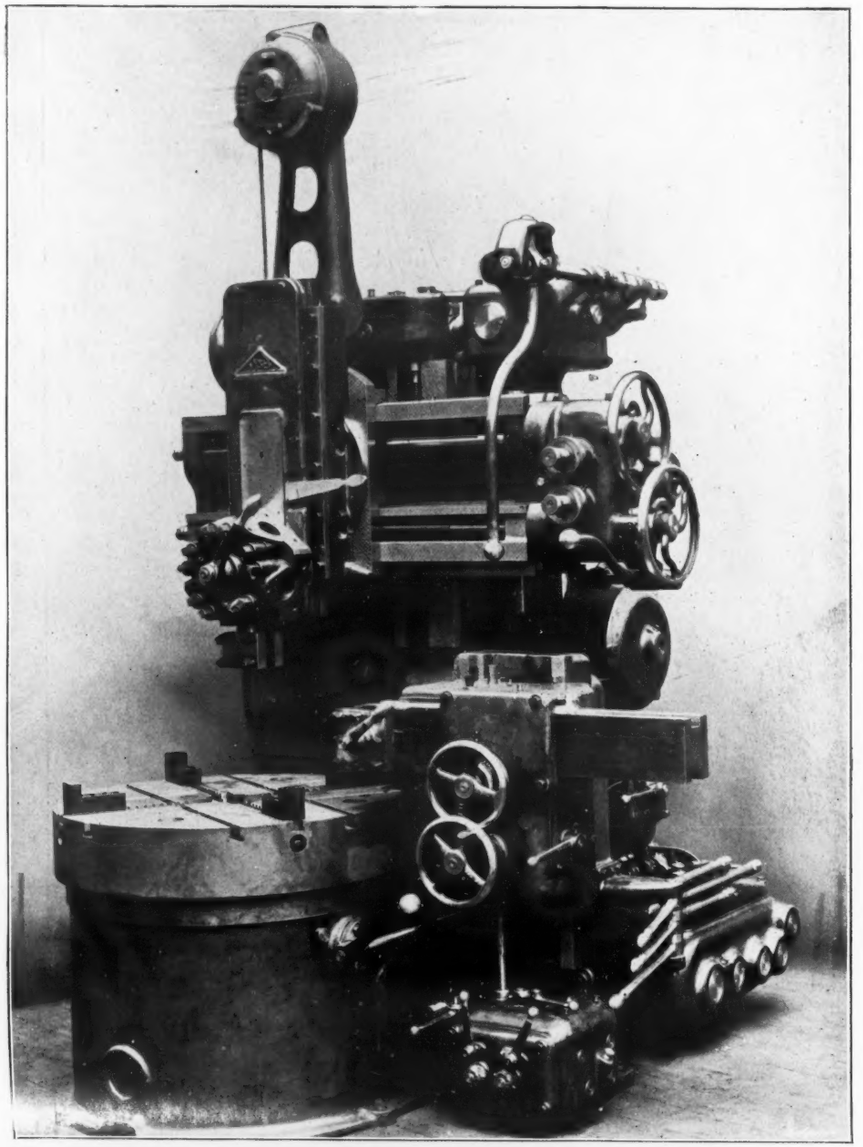


FIG. 5. 36-IN. VERTICAL TURRET LATHE.

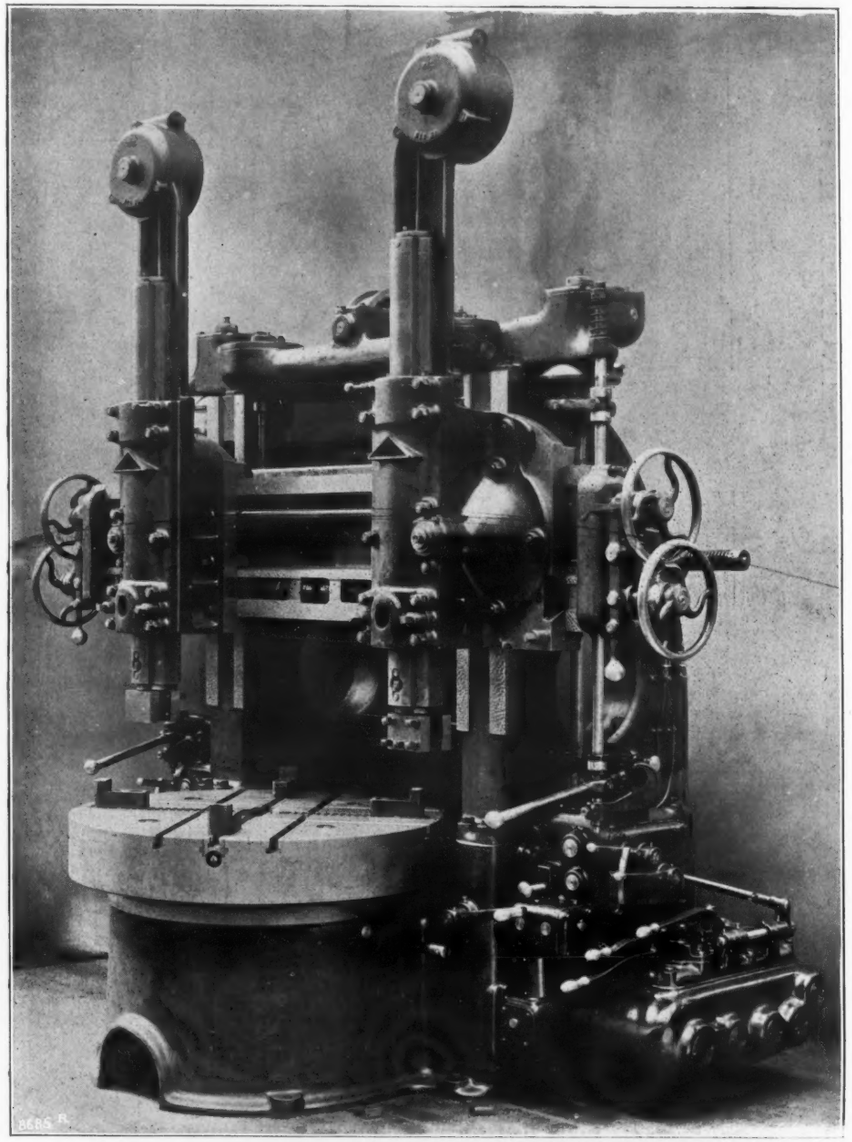


FIG. 6. 42-IN. DOUBLE RAM VERTICAL BORING MILL.

(*To face* p. 311.)

(To face page 311.)

Fig. 5. 36-In. Vertical Turret Lathe.

Fig. 6. 42-In. Double Ram Vertical Boring Mill.

HORIZONTAL SURFACING, BORING, DRILLING AND TAPPING MACHINE AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. H. W. KEARNS AND CO., LIMITED, ENGINEERS, MANCHESTER.

(*For Description, see Page* 314.)

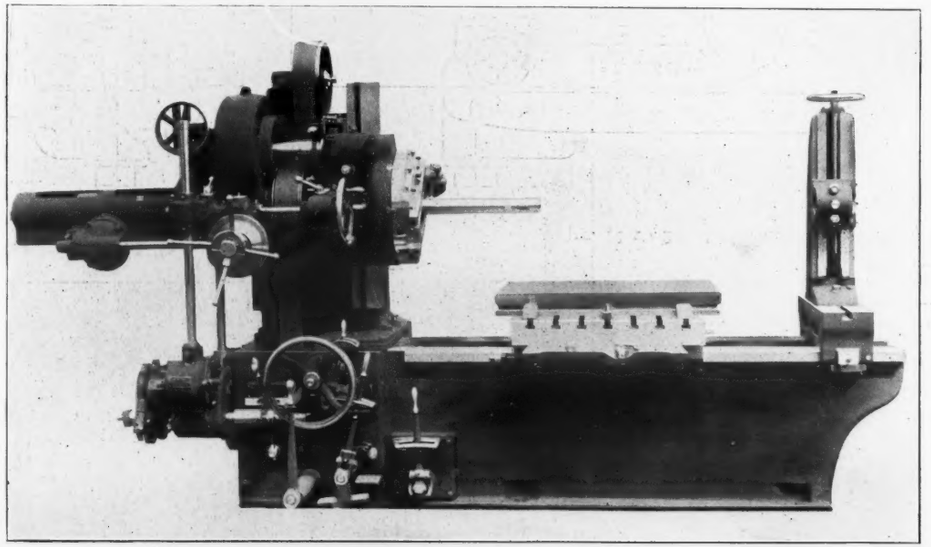


Fig. 16. Horizontal Boring Machine.

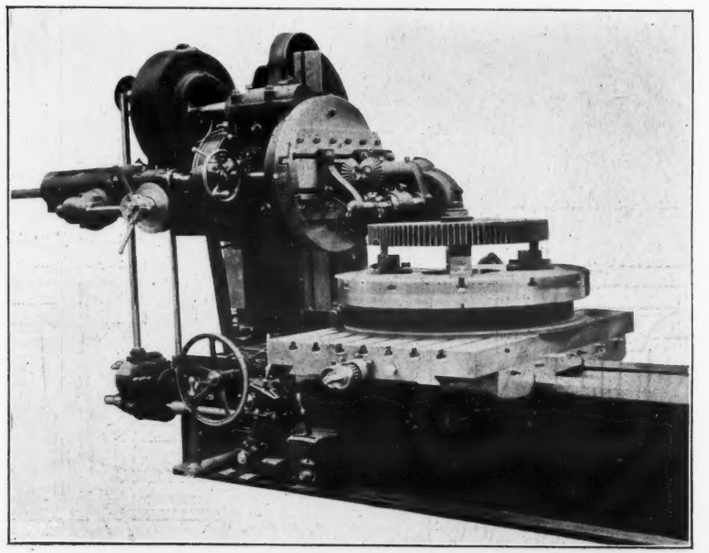


Fig. 17. Boring Machine Arranged for Gear Cutting.

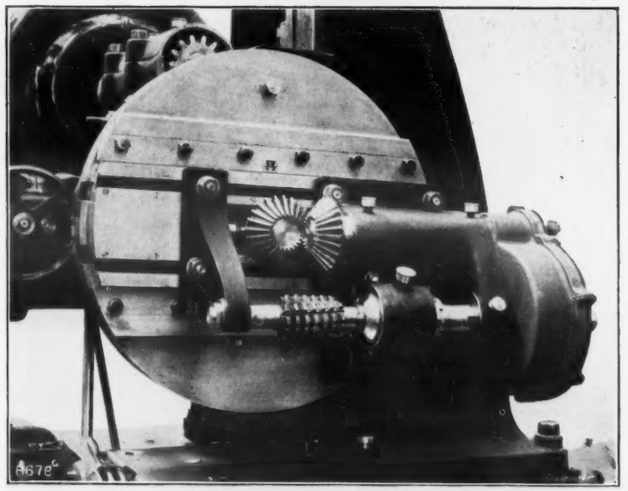


Fig. 18. Gear Hobbing Attachment.

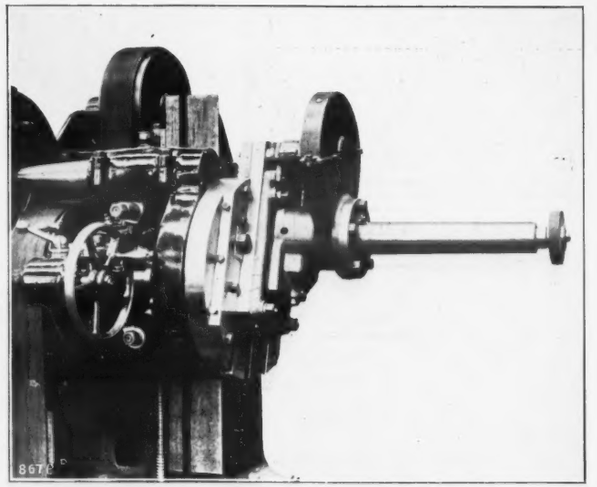


Fig. 19. Grinding Attachment.

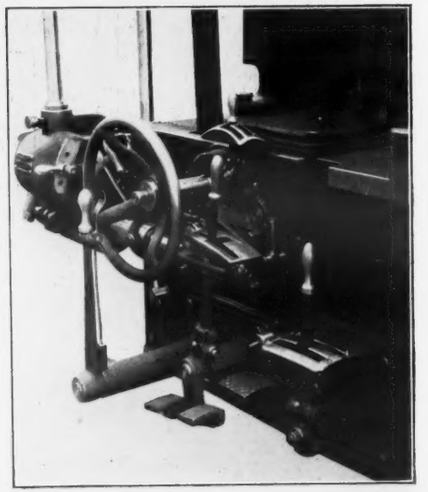


Fig. 20. The Controls.

DRILLING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. A. A. JONES AND SHIPMAN, LIMITED, ENGINEERS, LEICESTER.

(*For Description, see Page* 314.)

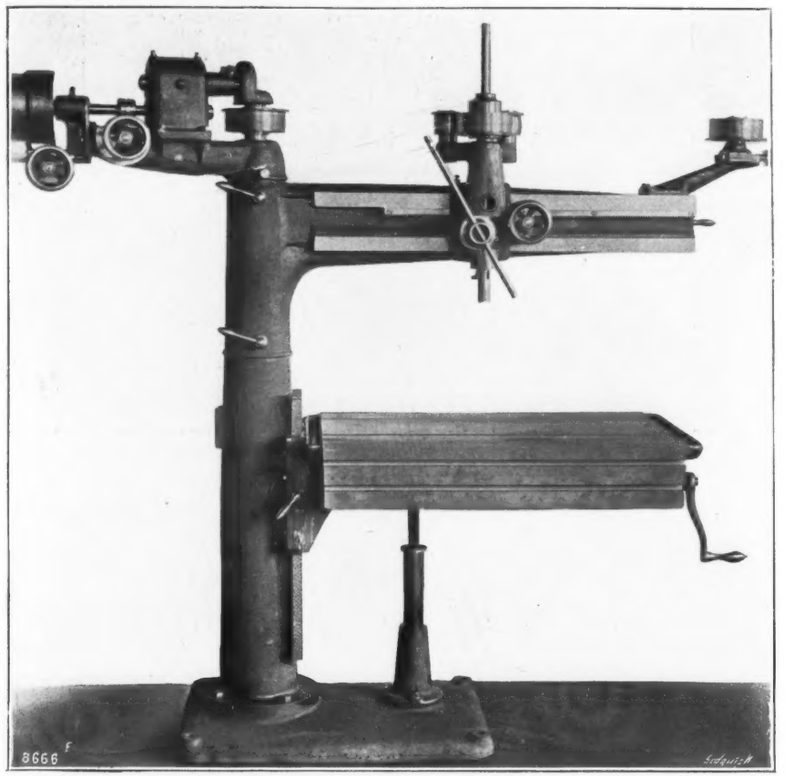
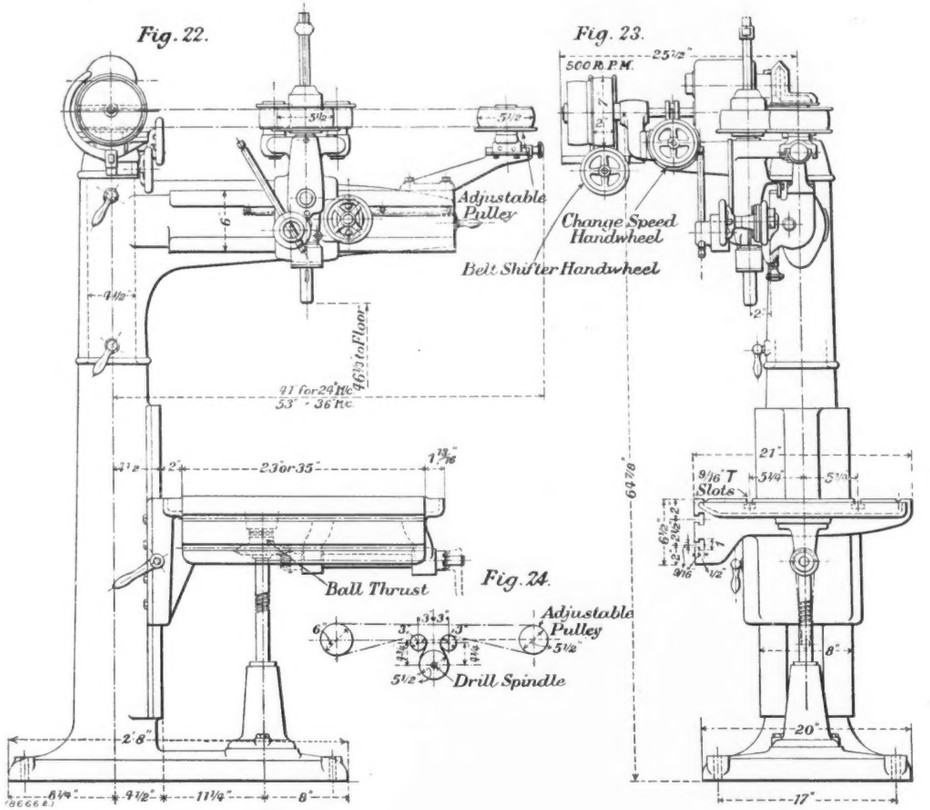
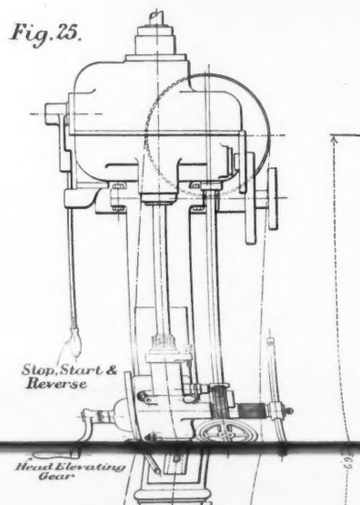
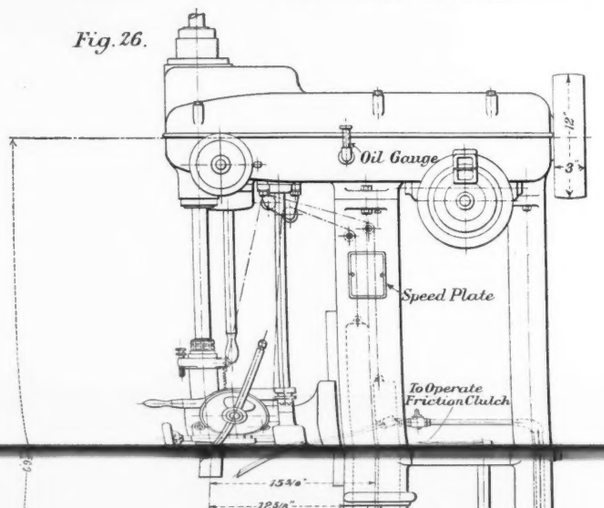


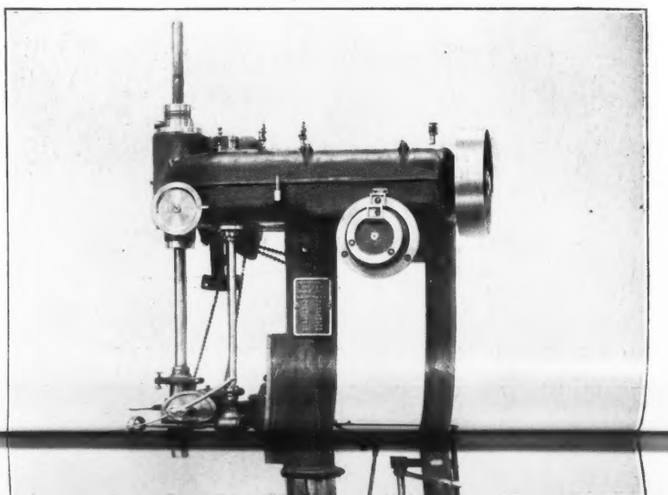
FIG. 21.

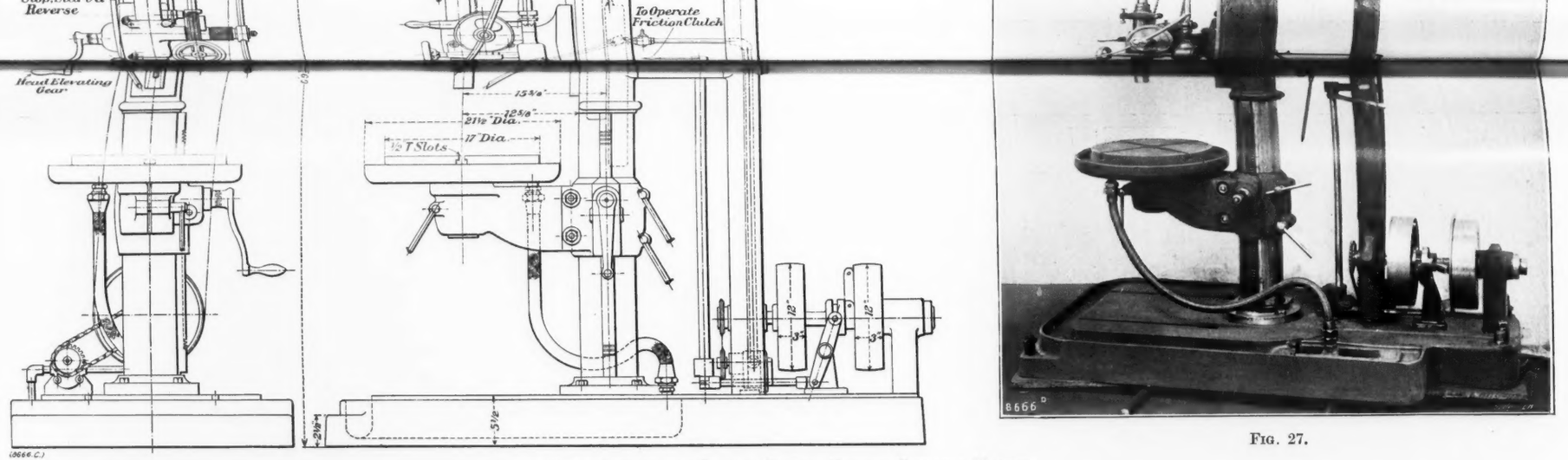


FIGS. 21 TO 24. 36-IN. SENSITIVE GEARED RADIAL DRILLING MACHINE.









FIGS. 25 TO 27. 25-IN. ALL-GEARED UPRIGHT DRILLING MACHINE.

FIG. 27.

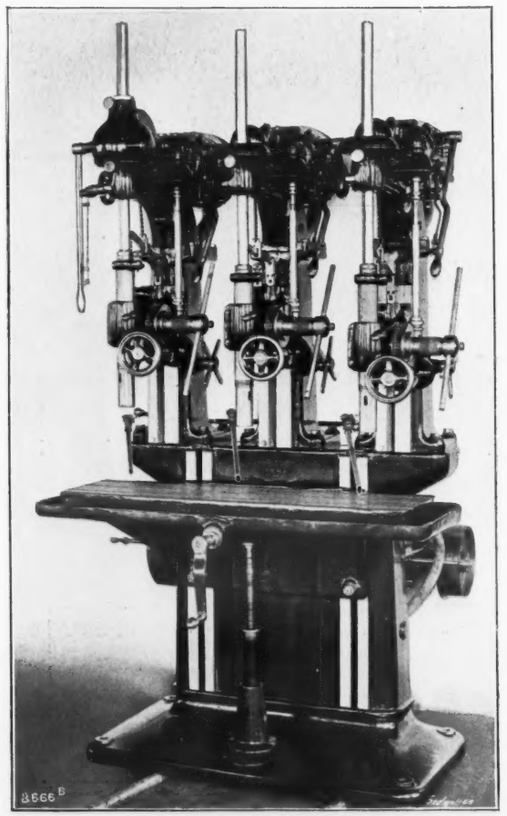
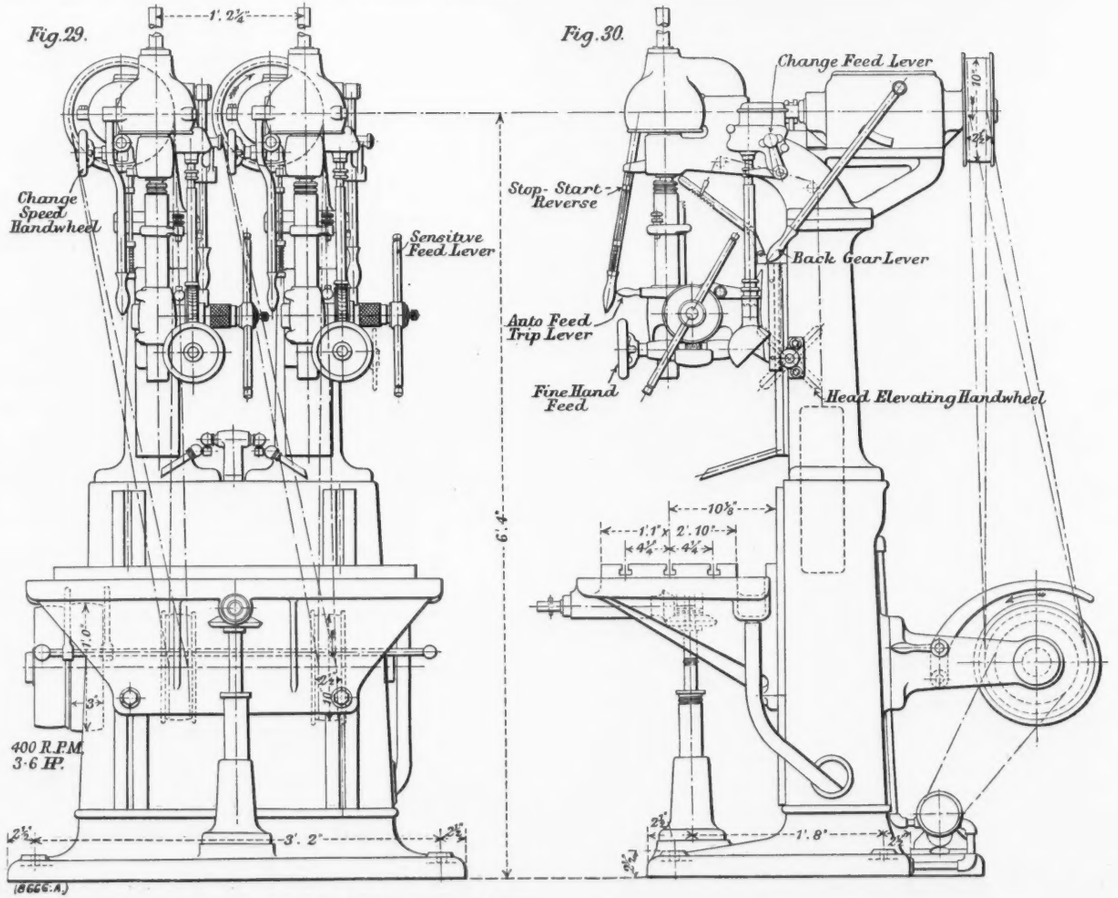


FIG. 28.

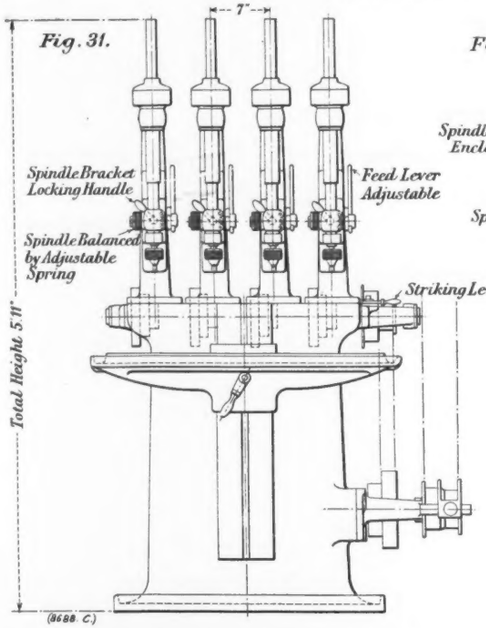


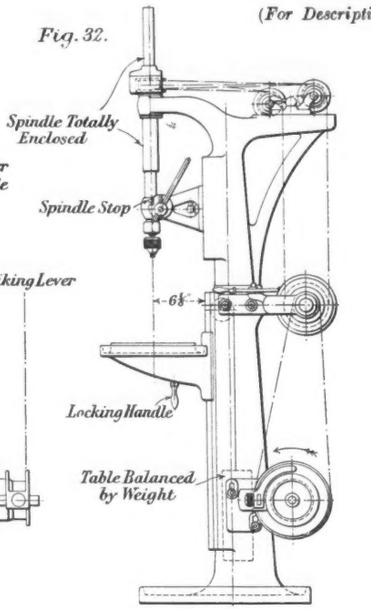
FIGS. 28 TO 30. MULTIPLE SPINDLE ALL-GEARED DRILLING MACHINE.

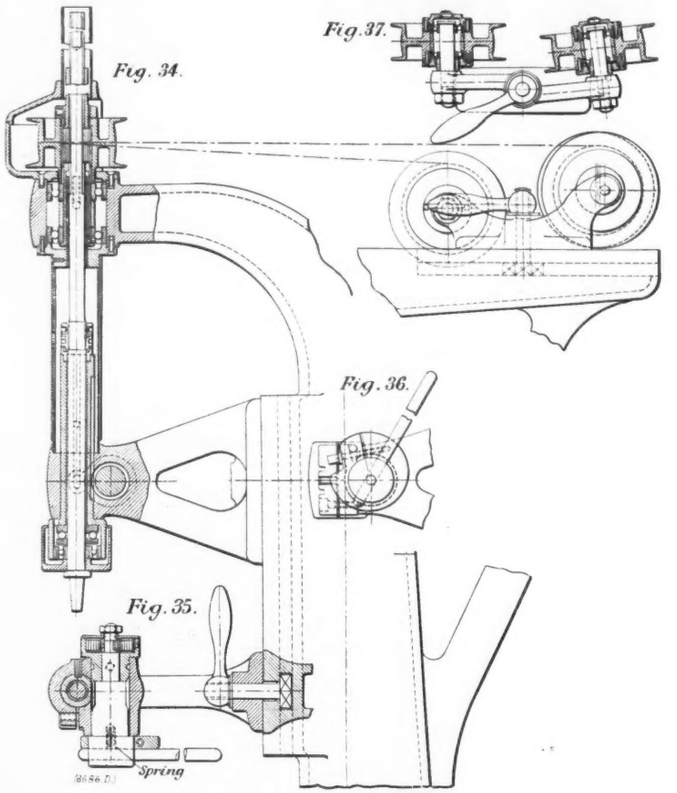
12-IN. HIGH-SPEED PRECISION DRILLS AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. FREDERICK POLLARD AND CO., LIMITED, ENGINEERS, LEICESTER.

(For Description, see Page 315.)







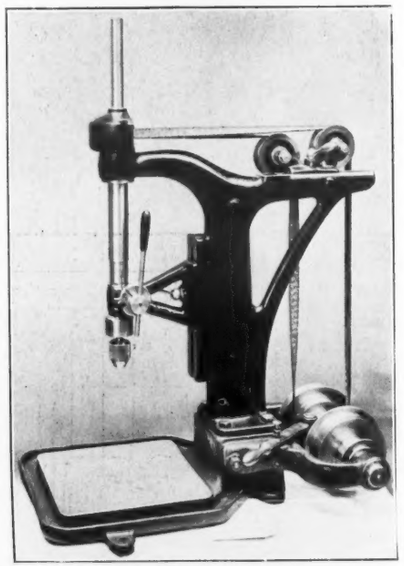
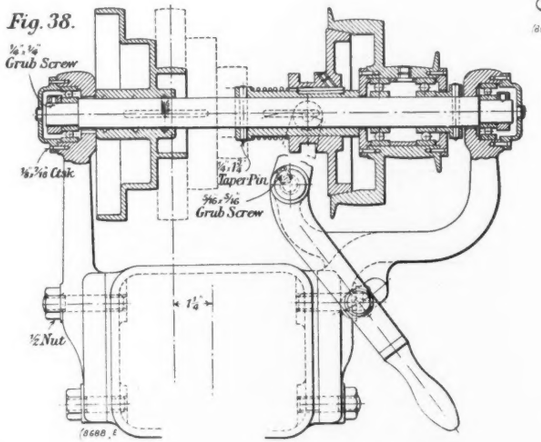
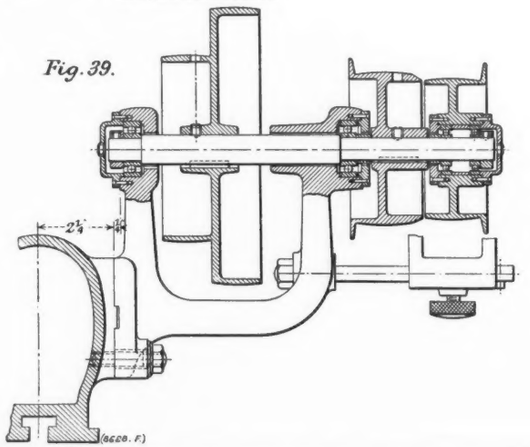


FIG. 33. BENCH TYPE.





(To face page 315.)

PLANO-MILLING MACHINES; THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY MESSRS. KENDALL AND GENT (1920), LIMITED, ENGINEERS, MANCHESTER.

(*For Description, see Page* 318.)

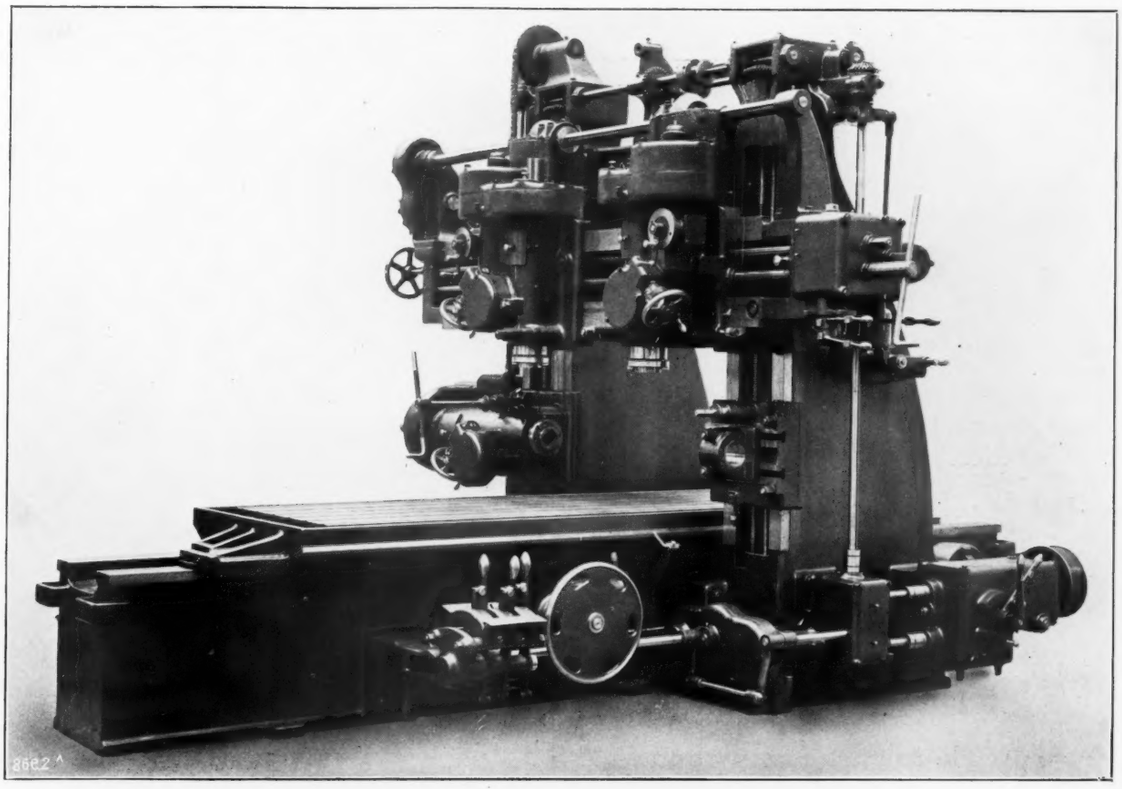


FIG. 50. VERTICAL AND HORIZONTAL SPINDLE PLANO-MILLING MACHINE.

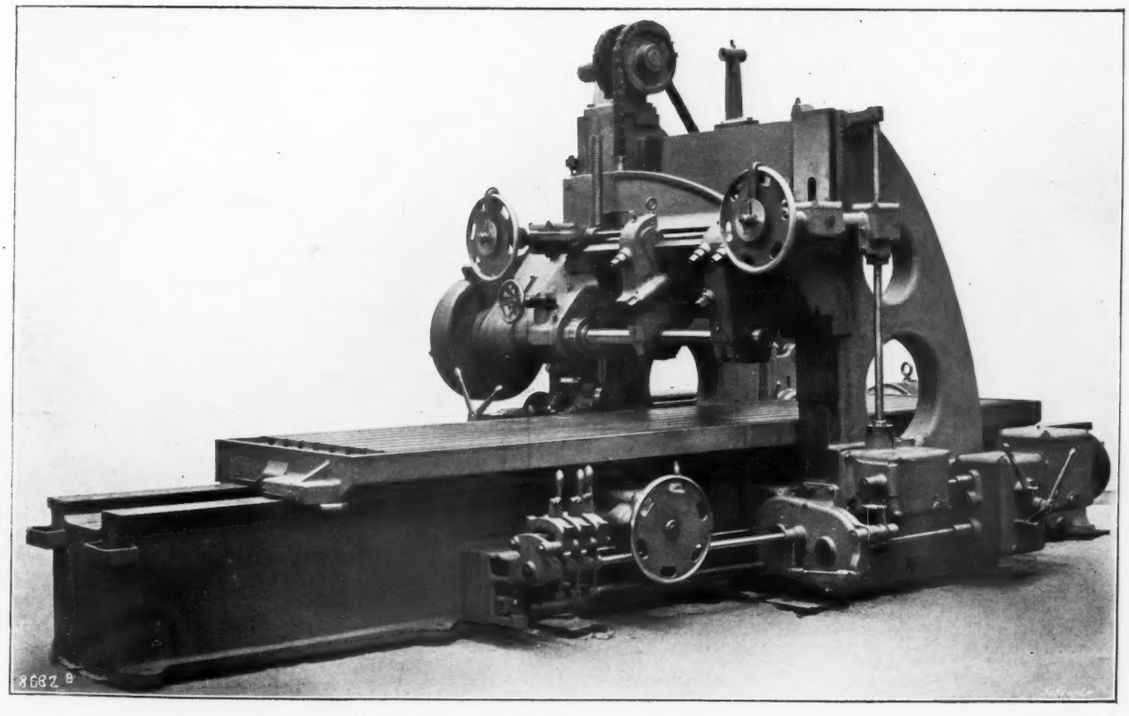


FIG. 51. HORIZONTAL SPINDLE PLANO-MILLING MACHINE.

(*To face page* 318.)

SURFACE GRINDING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

CONSTRUCTED BY THE LUMSDEN MACHINE COMPANY, LIMITED, ENGINEERS, GATESHEAD.

(*For Description, see Page* 318.)

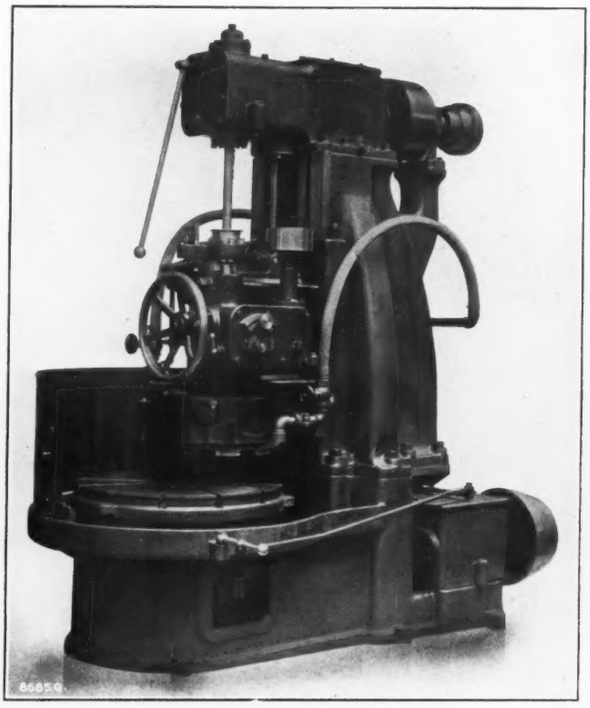


FIG. 52. GENERAL PURPOSE VERTICAL SPINDLE GRINDER.

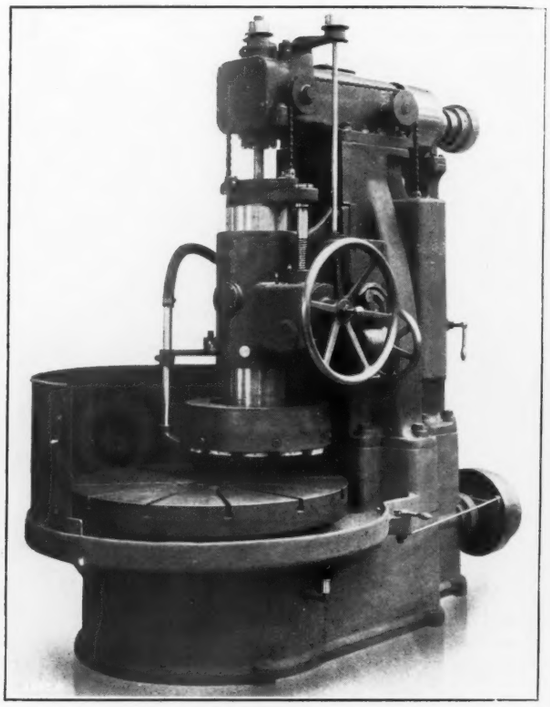


FIG. 53. LIMITED PURPOSE VERTICAL SPINDLE GRINDER.

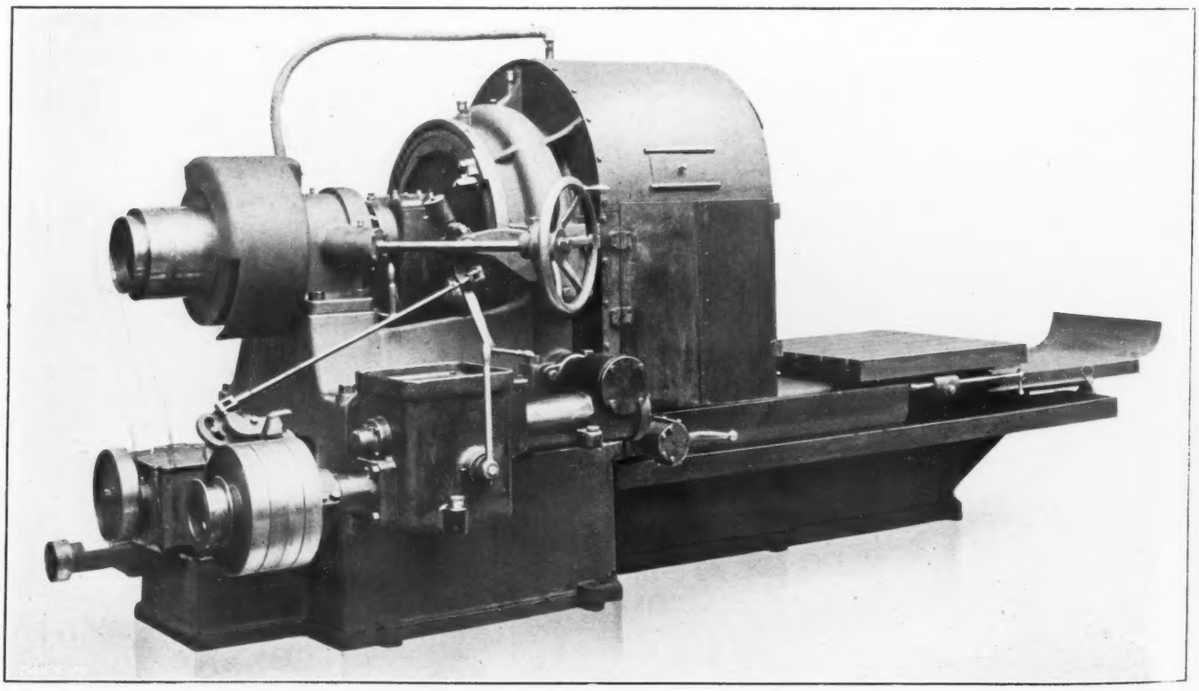


FIG. 54. PLANETARY HEAD HORIZONTAL GRINDER.

(*To face page* 319.)

ENGINEERING.

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One Two-Page Plate and Six One-Page Plates.—THE MACHINE TOOL AND ENGINEERING EXHIBITION.

ENGINEERING.

FRIDAY, SEPTEMBER 5, 1924.

AMERICAN BATTLESHIPS AND THE WASHINGTON TREATY.

DURING the past week the President of the United States has announced that his Government could make certain alterations to the main armament of the battleships of the American fleet without violating the Washington treaty. Indeed, if the press conveyed his utterance correctly, one can assume that the President went further, and hinted that the treaty actually gave his Government a right to alter the battleships. A later report, however, hints that the President may assert this right but not exercise it for the time being. These statements should not be discussed independently of their antecedents.

Rather more than a year ago, Mr. Denby, who was then Secretary to the Navy in the American Cabinet, urged Congress to vote money for increasing the gun range in thirteen American battleships. His argument was simple. British battleships could use their main armament against an opponent at a range of 23,000 yards: the greatest range of the American battleship armament was 20,000 yards. There could be no question of equality between two forces so differently equipped, as the one had an overwhelmingly tactical advantage over the other.

The subsequent history of this recommendation is not very clear; the naval committee of the House of Representatives certainly reported on it favourably, and said that, in their opinion, the alterations could be made without any violation of the Washington treaty. This alone would not have sufficed to persuade the American Congress to vote the money; but, almost simultaneously, Admiral Coontz reported on the state of the navy as revealed at the spring manœuvres off the Panama Canal. He drew attention to many faults and failings in the equipment of the fleet, and his report raised a great deal of very anxious comment in the press. The plea for increasing the range of the battleships' guns was for the moment lost in the bigger contention, that the naval ratios established by the Washington treaty had been upset by the failure of the American fleet to maintain itself on a standard of equipment equal to that of its principal rival, Great Britain. This general clamour did, however, have a great effect upon Congress. The money for altering the battleships' guns was voted; and it was only by a hazard of American parliamentary procedure that the matter was held over for final settlement until next session. Meanwhile, the British Government is reported to have notified America that, in their opinion, the alterations cannot be made without illegality. What process of reasoning has led the legal and naval advisers of the two countries to these opposite conclusions?

In the American view, there is only one clause in the treaty which could possibly be said to forbid the proposed alterations. It runs thus: "no alterations in side armour, in calibre, number or general type of mounting of main armament shall be permitted, ... "; after that there are certain specified exceptions, which the Americans consider are not to the point. They therefore claim, that the proposed alterations can be made without changing the "general type of mounting" of the main armament, and support their argument as follows: Five things are necessary to increase the range of the guns: (i) The gun port openings must be made larger; (ii) the elevating screws must be lengthened, so as to allow the breaches of the guns to be lowered further; (iii) some of the plates and framing under the guns must be cut away so as to allow the breaches to be lowered as far as the lengthened elevating screws permit; (iv) the position of the ammunition hoists must be altered; (v) the recoil system of the guns must be made more powerful. These alterations, say the Americans, are readjustments of parts of the existing mountings and no more. A gun mounting belongs to a "general type" by virtue of its design and the mechanical system under which it operates. A six-coupled locomotive belongs to a certain type of machine because it has six driving wheels, and not because they are of this or that diameter.

The American contention is plausible but extremely disputable, and British objections to it are threefold. First, a gun mounting, in combination with an explosive charge, is designed to give a gun a certain specified range. If it is so altered as to give the gun which is mounted on it qualities that it did not possess before, then, most certainly, the type of mounting has been changed. It is no answer to say that the alterations, taken one by one, leave the gun on the same type of mounting: they must be judged by their total effects and consequences. Nor is this all: the clause in the Washington treaty which prohibits alterations to the mountings, goes on to say that France and Italy can increase the armour protection and calibre of the guns of their battleships; and that Great Britain can complete certain alterations in the Renown's armour. If these exceptions to the general rule are given in such detail, is it conceivable that alterations of which no mention is made can be allowable?

In the second place, it can be maintained that the clause quoted is not, by any means, the only one which forbids the proposed alterations. The Americans argue that they are necessary to maintain the equal ratio between the naval forces of the two countries. In the British view the equal ratio was established by the lists of ships inserted in the first part of the second chapter to the treaty, in which each ship to be retained by the signatories was mentioned by name. These ships were taken to represent a certain combatant power, which, if altered, will not establish the equal ratio between the two navies, but upset it.

The third objection to the American argument is not quite so direct; but equally strong. It is

quite obvious that American naval experts conceived these alterations to be necessary after the treaty was signed. When the need for them was discovered, it was doubtless thought that the American fleet did not give the country the degree of security which was required of it. This, at all events, seems a fair interpretation of Mr. Denby's original plea; and it can certainly be said that the treaty made proper provision for questions of the kind. Article XXI of the third chapter runs thus: "If during the term of the present treaty the requirements of the national security of any contracting power in respect of naval defence are, in the opinion of that contracting power, materially affected by any change of circumstance, the contracting powers will, at the request of such power, meet in conference with a view to the consideration of the provisions of the treaty and its amendment by mutual agreement. In view of possible technical and scientific developments, the United States, after conference with the other contracting powers, shall arrange for a conference of all the contracting powers, which shall convene as soon as possible, after the expiration of eight years from the coming into force of the present treaty, to consider what changes, if any, in the treaty may be necessary to meet such developments."

This clause, does not deal with gun mountings or armour; but it certainly deals with the American procedure. If the alterations to the battleships' guns involve a question of American naval defence—and it can certainly be claimed that they do—then, the American government has no right to carry them out without previous consultation with the co-signatories. If, on the other hand, they may be regarded as necessary in view of "technical and scientific developments," then the American government has no right to give effect to them before eight years are out and another conference has been summoned. To sum up, therefore, one may say that the proposed alterations are intrinsically illegal; and that, if they were not, the proposed method of executing them would be.

EFFECTS OF THE NEW UNEMPLOYMENT ACT.

In our article of May 2 (page 580) on the Unemployment Insurance (No. 2) Bill we indicated some of the changes in the law of unemployment insurance which were involved in that highly controversial measure; but as the Bill, with certain amendments, has now received the Royal Assent and is in full operation, a few notes as to its effect may be useful. The rates of benefit have been increased in some instances and are now as follows: for men, 18*s.*; for boys of 16 and under 18 years of age, 7*s.* 6*d.*; for women, 15*s.*; and for girls of 16 and under 18 years of age, 6*s.* The rate for dependants such as a wife, &c., remains at 5*s.*, but that for dependent children has been increased from 1*s.* to 2*s.* for each child. The waiting period has been reduced to three days; and uncovenanted benefit, which was payable in the Ministry's discretion and was better known as the dole, has now become "extended benefit" and, under certain conditions, is to be paid to the unemployed as a matter of right until June 30, 1926. Before that date the whole subject will, no doubt, be reviewed by Parliament. The Minister's power to approve of special contracting-out schemes, instead of being abolished, as was proposed in the Bill, is merely suspended until the expiration of one year from the time when the unemployment fund becomes solvent.

There was much controversy over the trade dispute disqualification. As a result of the new Act, the disqualification is not to apply in any case in which the insured contributor proves that he is not participating in or financing or directly interested in the trade dispute which caused the stoppage of work, and that he does not belong to a grade or class of workers members of which are participating in or financing or directly interested in the dispute. The House of Lords attempted to make it necessary that the insured contributor should prove also that he did not belong to a trade union which, either by itself or through another trade union or federation or association of trade unions, was participating in or financing or directly interested in the dispute. This was, in effect, to reinstate that part of Sir John Simon's amendment in the House of Commons which Sir John withdrew in response to the Minister's entreaties. But the Speaker of the House of Commons ruled that the matter was privileged, as the Lords were not entitled, where a sum of public money was involved, to alter the conditions under which the money became payable to those entitled to receive it. The Commons therefore disagreed with the amendment, and the Lords acquiesced. It is true that if the Lords' amendment had been given effect to, the managers of the labour exchanges would have required to question the applicants for benefit as to their membership of trade unions—which might have been undesirable; but it is difficult to see how the officials are to be satisfied that a claimant does not belong to a grade or class of workers, which are participating in or financing or directly interested in a dispute, if they do not ascertain whether he is a member of a trade union which is doing any of these things. In any event, what is to be regarded as proof, in terms of the statute? And how is the claimant to prove a negative?

The insurance officer, the Courts of Referees and the employer will have their difficulties in dealing with claims under this clause; but there is a further extraordinary clause in the Bill, to the effect that an insured contributor may avoid the trade dispute disqualification if he proves that the stoppage "is due to an employer acting in a manner so as to contravene the terms or provisions of any agreement existing between a group of employers where the stoppage takes place, or of a national agreement, to either of which the employers and employees are contracting parties." This was moved as an amendment in committee and was defeated there; but at the report stage in the House of Commons Mr. G. Spencer brought up his amendment again, and the Minister of Labour, after stating that he was in doubt as to how the proposal would work, and doubtful as to what the full effect of the amendment would be, suddenly announced that he would go into the Lobby in favour of the amendment, and the House of Commons, apparently without understanding the amendment, agreed to it. It is indeed difficult to say what the words mean. Mr. Spencer indicated that the amendment had been designed for the purpose of making agreements between employers and employees "more sacred," so that where a local or a national agreement had been made between employers and employees, and any employer desirous of breaking the agreement offered terms less favourable than those provided for in the agreement, the workers should not be disqualified from receipt of unemployment benefit if they went on strike in order to resist the employer's action.

The new provision, however, goes far beyond this. The wording is obscure, and even ridiculous, but as it stands it seems to amount to this, that if the claimants prove that the stoppage is due to a contravention, on the part of their employers, of any agreement between their employers and the workers, the trade dispute disqualification is not to apply. Now in most trade disputes there are allegations and counter-allegations of breach of agreement, and the real causes of the dispute are often so obscure that Courts of Enquiry have to be set up by the Minister of Labour in order that the Government and the public may know what the trouble is about. In the case of the recent building dispute Lord Buckmaster, after a day or two's labour, still found himself at a loss to know what the real dispute was. It follows, therefore, that those responsible for the payment of unemployment benefit will be involved time after time in judicial investigations as a preliminary to the payment or refusal of benefit. They will have to ascertain, firstly, whether there is an agreement as alleged by the workers; secondly, what the agreement means, and this is often a matter of the greatest difficulty; and thirdly, whether in the circumstances it has been broken by the employers. To our minds this is altogether wrong. The administration of the unemployment fund should be, so far as possible, purely a matter of administration. It is true that before the new Act came into operation questions of fact had often to be investigated and decided before benefit could be paid, but the new provisions involve the decision of questions of law as to the meaning of agreements, and questions of mixed law and fact as to whether the agreements have been broken, and they will inevitably result in a large part of the unemployment fund being diverted from its proper objects to the subsidising of workers who are parties to trade disputes.

Already in different parts of the country Courts of Referees have felt themselves constrained by the clause to award benefit to thousands of persons who are on strike, and if this is to continue, the solvency of the unemployment fund may be indefinitely postponed. We understand that these cases are under appeal to the Umpire, and as they are in effect *sub judice* we do not wish to say one word as to whether the strikers are or are not entitled, in terms of the new Act, to the benefits which they claim. We are concerned not with particular cases but with the wording of the statute, and we are sure that the House of Commons, when it assented to Mr. Spencer's confused and badly drafted amendment, never imagined that it would lead to benefit being awarded at the rate of thousands of pounds per week to persons actively and directly engaged in trade disputes. It is an instance of hasty legislation, calling for speedy amendment.

THE PRESENT INDUSTRIAL POSITION OF FRANCE.

Unemployment, the cause of distress to the people of many countries, the relief of which has been encompassed with considerable economic difficulties, is practically non-existent in France. Indeed, the industry of the country has been able to absorb the activities of thousands of immigrant workers. These—mainly of Italian, Polish, Belgian or Spanish nationality—have settled there and, although the official figures do not include coal miners or agricultural workers, the two classes most in demand, the position may be gauged from the fact that the recorded figures for other workers reached during last year no less than 6,000 immigrant workers in a week. This is not, however, the only feature of industrial interest in France to-day, for the industrial capacity of the country has been permanently increased. Alsatian ores, potash and oil have added to the national resources. The manufacturing capabilities have also been greatly increased by the acquisition of the well-developed and varied engineering and textile industries of Alsace. Expansion has, however, been mainly caused through the reconstruction of almost the entire range of textile industries, of coal and iron mines, metallurgical and engineering works, glass and chemical works, in the devastated areas. In addition to this factor it is to be noted that industry was transplanted during the war from these areas to others more remote from the seat of operations and old factories were re-established and new ones built, which are all available and, indeed, are in use at present. France thus finds herself in the position of having her manufacturing industries completely modernised and equipped with new plant.

The recent publication by the Department of Overseas Trade of a Report on the Economic Conditions of France to June, 1924, which was prepared by Mr. J. R. Cahill, the Commercial Counsellor at His Majesty's Embassy, Paris, has placed at the disposal of those interested in French trade a great amount of useful information on the progress made last year and also regarding the prevailing conditions and tendencies. This report is published by His Majesty's Stationery Office at a price of 6*s.* net. From it we learn that the great industries have consolidated their interests for the better meeting of international competition, and influences in foreign trade have been greatly extended. In 1922 the foreign trade of France had already exceeded the pre-war figures in weight, and that progress is still being maintained may be judged from the fact that, in the first six months of 1924, the exports exceeded those for the same period in 1923 by 2,300,000 tons. For the same interval imports were improved by 2,500,000 tons, almost entirely due to the importation of raw materials. Trade with Great Britain in raw materials was improved, but in the sphere of

manufactured goods a reduction was shown. Some efforts have been made to deal with the serious condition of public finances by fiscal reform measures adopted last March, and by retrenchment in the administrative services.

For all practical purposes of mere industrial output the reconstruction of the devastated areas may be considered as completed. The damaged mines, which only yielded 1,500 tons of coal in January, 1919, were able to produce 1,260,000 tons last May, and the surpassing of the pre-war figures may shortly be anticipated. Provision has been made for the recovery of the by-products of coal, and the under-production of coke has been so far repaired that five million tons a year are now produced, which is over 60 per cent. more than in 1913. Large increases have been made in the exportation of potash to markets formally held by Germany. Agriculture alone shows little progress, owing, it may be mentioned, to the acute shortage of labour, but the main crops, wheat and sugar-beet, are regaining their former position.

The French Government has maintained its policy of protection, and has continued to apply to the basis duties of 1910 the system of increased coefficients, which was introduced in 1919, to provide the same effective protection, under the present conditions of franc depreciation, as was then obtained. It may be remembered that these coefficients have been increased from time to time, although some reductions were made in December, 1922. Further modifications were proposed in July, 1923, but have been held in abeyance, pending the putting into effect of a commercial treaty with Belgium, which that country has so far failed to ratify. As regards the minimum rates to which British goods are entitled, increases running up to 700 per cent. have been imposed. Coal products, which are the most important imports from Britain, are still admitted at 1·2 fr. per metric ton. Fine tool steels show an increase of 160 per cent., while other special steels have higher duties by either 130 per cent. or 90 per cent. Motor-cars, which before the war paid only 12 fr. to 100 fr. per hundred kilogrammes, now have to pay 45 per cent. of their value.

The expansion of British trade with France, particularly in manufactured goods, was hampered in 1923 to an even greater extent than formerly by the continued depreciation of the franc and the wide fluctuations in exchange rates. Customs duties, which are heavier on manufactures than on raw materials, also acted as a deterrent, but the expiration of the law of 1916, by which duties might be increased by decree, relieved traders in the United Kingdom from the anxiety caused by the liability to sudden changes in the tariff. Despite the adverse conditions, the value of French importation from the United Kingdom during 1923 rose by 1·9 milliards of francs, as compared with an increase of less than 400 million francs in 1922. This increase was mainly due to coal, which represented two-fifths of the value of the total importation from Great Britain. The situation will now be affected by the resumption of deliveries from Germany, by the increased production of coal and coke in France, and by the electrification of railways which formerly made use of British coal, such as the Paris–Orleans and the Midi. British coal exporters may yet be able to take advantage of any appreciable improvement in the relationship of the franc to the pound. A heavy decline was again shown in 1923 in the importation of steam plant and other machinery from this country, from 30,858 tons to 25,265 tons, although the value remained stationary at about 211 million francs. Textile machinery declined, as the re-equipment of the factories in the devastated areas was completed by the end of 1922. It should be noted that the United States have increased their sale of engines and machinery in France during 1923, the amount rising to 38,772 tons as compared with 23,134 tons in 1922, and the value to 228 million francs from 134 million francs. The value of ships bought from the United Kingdom declined during the year from 158·2 million francs to 91·6 million francs. French exports to the United Kingdom rose in 1923 from 3,960 million francs to 6,154 million francs, and represented over 20 per cent. of the total exports. Canadian trade has been dealt with separately in the French returns since 1922. The year 1923 witnessed an importation from Canada of more than double the value of the previous year, the increase being mainly due to cereals. The conclusion of the Franco-Canadian Convention is likely to encourage the Canadian export trade, which is developing satisfactorily, especially in wood and engineering products.

The machine tool industry of France has made great progress since the war, but is not yet able to meet the home requirements and orders must still be placed in America, Britain and Germany. Increased activity may be anticipated, however, as a result of the growing capacity of France to produce special steels and the increased tendency towards specialisation in production. Nothing very considerable has yet been done to obtain orders from abroad, but a central export agency has received an order from China of the value of 1½ million francs. The French motor-car industry shows marked improvement due to the adoption of methods of mass production and to the condition of foreign exchanges. For the first three months of 1924 a total weight of motor vehicles of all classes of 16,700 tons was exported. This was more than double the figure for the same period in 1923. It is anticipated that increased trade with Great Britain will be obtained through the abolition of the McKenna duties. Aircraft construction is still on a small scale, but the creation of new air routes and the anticipated increase of use of aircraft in commercial and military operations has led to the laying down of new works.

Considerable progress has already been made in France in railway electrification and the Paris-Orleans, the Paris-Lyons-Mediterranean and the Midi Railways have now got schemes in hand, involving in each case stretches of about 2,000 miles of line. These plans affect about one-third of the total French railway mileage. The building of electric locomotives has been pressed forward and a large works has been established at Tarbes which has 60 locomotives under construction at present for the Midi. The Paris-Orleans Railway have under order 80 electric locomotives which are to be built by the Société d'Etudes pour l'Electrification des Chemins de Fer Français, and construction has been started on part of an order for 200 electric locomotives, of which 80 are to be of the Oerlikon type of 1,720 h.p. Five of these are to be built at the Oerlikon works near Zurich, and the remainder at the French works at Ornans in connection with the Société de Construction des Batignolles and the Compagnie Générale de Construction des Locomotives.

ACCIDENTS IN SHIPBUILDING AND SHIP-REPAIRING WORK.

INVESTIGATIONS of the causes contributing to the accident rates in the shipbuilding and ship-repairing industries have been conducted at the request of the British Government at various periods since 1901, when an enquiry was held by one of His Majesty's Inspectors of Factories. Since 1914, when the latest Shipbuilding Regulations took effect, there has been a period of abnormal conditions. It was thought that as the period of accelerated war-time production and the present experience of trade depression were scarcely comparable with the activities in the earlier normal times, a further enquiry was necessary. For this purpose the Right Hon. W. C. Bridgeman, in April, 1923, when he was Secretary of State for the Home Department, set up a Departmental Committee, under the chairmanship of Mr. Godfrey Locker-Lampson, to report on any further measures that were considered advisable. This Committee has now concluded its work and the Report presented to His Majesty's Government has now been published by the Stationery Office.

In the Report comment is made on the fact that the definition of a shipbuilding yard in the Factory and Workshop Act of 1901 does not cover a harbour or a public wet dock in which a vessel may be repaired and recommendations were made that all repair work, no matter where conducted, should be subject to Regulations. Proposals were made by the Committee that gangways should be provided with boards at the sides projecting 6 or 8 in. above the floor of the gangway, in addition to the two hand-rails, in order to prevent the fall to the ground of anyone slipping on the gangway when it was wet. The provision of a level platform between the top of the gangway and the cross gangway to the deck of the ship was also advocated. To prevent the slipping of ladders it was suggested that they should be securely lashed as near to the top as possible. For this purpose exception was taken to the use of fibre rope because of its liability to wear through by chafing against the edges of the plates. Lengths of wire, chain and electric cable were advocated as serving the purpose in a more satisfactory way. Unless there was other adequate handhold it was suggested that all ladders should extend well above the place to which they gave access, but no definition of minimum requirement was regarded as necessary. The use of single planks as a means of access between one place and another was thought to constitute a serious danger. It was suggested that at least two planks placed side by side should be used. Until a strake of plates was in position on each side of the deck sufficient planks for the purpose of access, both fore and aft and athwartship, should be provided. It was suggested that if fitted covers were provided for all openings not otherwise protected, if a system of safety education were instituted and if effective supervision were made to see that the covers were maintained in position, the number of accidents by falls through openings would be substantially reduced.

It was recommended that all inside hanging staging, including that supported by brackets, the outside staging at the fore and aft ends, and the stage planks in way of gaps caused by uprights, should be adjusted by staging gangs specially, though not necessarily exclusively, employed for the purpose. The question of the use of single planks was again referred to in dealing with working stages and it was suggested that no stage at a height of 6 ft. or more above the ground, deck or tank top should consist of less than two planks in width. All hanging stages supported by wire or hemp ropes or chains should be secured in such a way as to prevent swinging out from the side of the ship. Experiments were suggested by the Committee into the question of providing goggles allowing wide vision, efficient ventilation and affording sufficient protection to the eyes from flying particles of steel and other matter. When the present difficulties in the provision of suitable goggles were surmounted it was suggested by the Committee that their wearing should be made compulsory on all caulkers, scalers and chippers. That all men engaged in handling plates should be provided with adequate protection for their hands was another of the many proposals of the Committee.

In painting with quick-drying paints troubles of the nature of gassing have been experienced. For their prevention the provision of adequate ventilation was requisite. Another recommendation was that oxy-acetylene burners and electric welding equipment should not be used in confined or enclosed spaces unless the ventilation requirements were met. Breathing helmets were necessary when the sludge or deposit was being removed from oil tanks prior to repair. The practice of one squad of men working on a staging immediately above another squad, though necessary when work had to be speeded up, was thought very dangerous and every precaution should be taken to prevent the fall of tools or materials. Investigations were suggested into the effects of annealing chains as ordinarily practised and to devise means of correct normalising. Pending the carrying out of these investigations, it was suggested that annealing of chains at definite intervals should be made compulsory. For electric welding it was suggested that a direct current supply, at a pressure not more than 120 volts, should be used, although it was suggested that alternating current might be used where the use could be shown to be as safe as direct current at 120 volts. Proposals were made that for the first six months of the employment of young persons under sixteen, they should not be required to work on the ship or above ground, and that during that time employers should take steps to instruct them in regard to the risks that they were likely to encounter. Education in methods of safe working,

the appointment of "Safety First" committees and training in First Aid, were regarded by the Committee as essential.

We have referred in a general way to the main proposals submitted by the Committee, but whether many of them will be productive of a reduction in the number of accidents experienced seems open to question. It might be emphasised that when the work in shipyards was carried out at great speed and with many more than the normal number of employees, during the period of the war, the total annual number of deaths through accidents averaged out at about the same as in 1912 and 1913, while when slackness of trade became the condition in 1920, the fatal accident rate increased. We have no desire to belittle any earnest endeavour to make any type of industrial work as safe as possible for those working at it, but we trust that whatever is done may not have the effect of so hampering the work that the costs of production, the most important factor in obtaining work at all, may be appreciably increased. Some of the recommendations are so lacking in definition that it is hard to see how they could be put into force. For example, alternating currents are suggested as allowable for welding purposes if the danger to the worker is not greater than with direct current at 120 volts. It is difficult, if not completely impossible, to see how any decision to meet this requirement could be arrived at, for what the degree of danger is cannot be specified. Carelessness regarding danger is largely born of familiarity, and though much may be done by the inculcation of Safety First methods, we cannot expect that men will always avoid taking risks in work with the circumstances of which they have acquired full knowledge through years of experience.

NOTES.

The William Froude National Tank.

It is interesting to learn from the report* of the Advisory Committee on the working of the William Froude tank at Teddington during the past year that the slackness in the shipbuilding trade has not been fully reflected in the diminution of the work done at the tank for private firms. In spite of the depression the number of models tested for private firms during the twelve months ending on November 30 last was 56, as against 35 in 1922. Probably the greater insistence of shipowners on efficiency is not without its influence in this matter. In one case during the year the modifications made due to the tank experiments resulted in a saving of 10 per cent. of the horse-power. The changes made involved, in this case, no alteration in either the displacement or the dimensions of the vessel. It is also of interest to learn that shipowners are now more inclined than formerly to aid in research at the tank. Up till quite recently the whole burden of experimental work fell on the shipbuilder, but the Council of the Chamber of Shipping has during the year under review voted a sum of £1,000 in aid of the investigations in progress at Teddington. Moreover, various shipowners are giving facilities for the study of the behaviour of ships at sea, which is a highly desirable supplement to the tank experiments. Other work in which shipowners have displayed interest and given aid has been in connection with the study of the effects of shallow water on the steering qualities of a ship. Much work on this head has been carried out to the order of Sir Thomas Fisher, of the Canadian Pacific Line, and also for Sir John Thornycroft and for Sir J. Biles and Co., whilst the Commonwealth Line gave a free passage out and home to an observer who was sent to study the matter in the Suez Canal. Acknowledgment is also made in the report of the help received from Lord Inchcape, and from M. Chateauminois, the principal agent of the Suez Canal Company at Port Said. During the present year it is proposed to start the study of the effect of waves and pitching on the revolutions per minute of the propellers, and the general efficiency of propulsion in rough-water conditions. Further comparisons will be made of the tank results and trial trip figures, and accordingly the tests of the three ships to be made by the Marine Oil Engine Trials Committee will be attended by the tank staff. As the mechanical efficiency of the engines will be known, and torsionmeters are being fitted, a direct comparison with tank data will be practicable.

* Report of the Advisory Committee for the William Froude National Tank for the year ending December 31, 1923. H.M. Stationery Office. [Price 6d. net.]

The Acidity of Raw Rubber.

The fourth session of the Institution of the Rubber Industry was opened last Monday with a paper on "The Acidity of Raw Rubber," in which Professor G. Stafford Whitby, of McGill University, Montreal, drew attention to the marked beneficial influence of the acid constituents of the so-called rubber resins upon the ageing, tensile strength, plasticity and rate of vulcanisation of rubber. He had himself recorded the presence of these acids for the first time last year, and the question has its ironical aspect, since acids have been so far considered objectionable in rubber. A very small portion of these acids, Dr. Whitby stated, was water-soluble and technically of no use; that portion would be equivalent to 0·01 per cent. of acetic acid, and the very interesting, mainly chemical, discussion of the paper, clearly brought out the fact that the more acetic acid was used for the coagulation of the latex, the less of it was found in the rubber. Dr. Whitby isolated three acids non-soluble in water—a little of a solid acid, a new compound which he calls heveic acid, $C_{20}H_{40}O_2$, and two liquid fatty acids, oleic and linolic, the latter predominating. Hevea rubber contained from 1 per cent. to 2 per cent. of these acids; but different rubbers varied much, and hevea rubber, generally considered typical, was in fact unique, as its resin was highly saponifiable and optically inactive. When rubber was kept for years, especially in hot climates, and when in thin samples, the acid contents diminished to one-fourth and less in twenty years, owing to an oxidation of the linolic acid. The presence of these acids, which were dissolved in the rubber and not merely absorbed, facilitated the emulsion of the caoutchouc globules and promoted the swelling, and hence the solubility of the raw rubber in various solvents, while reducing the viscosity. The acids had apparently no influence on the vulcanisation by sulphur alone, but they were of first-rate importance for the vulcanisation in the presence of accelerators, not only inorganic, but also organic, probably by acting as solvents for litharge and zinc oxide, &c., which strongly activated the accelerators. The Institution of Rubber Industry, Mr. Fordyce Jones announced when opening the meeting, has now 634 members.

The New Factory Bill.

The memorandum of the chief engineer, which is issued annually to the members of the Manchester Steam Users' Association, is this year devoted almost entirely to a criticism of the new Factory Bill. In the first place, Mr. Stromeyer raises the objection that boiler owners were not consulted in any way prior to the preparation of the Bill. The Manchester Steam Users' Association was founded by Fairbairn, and is controlled by factory owners, and its history is a striking illustration of the falsity of the popular agitator's assumption, that the capitalist is solely actuated by greed and cares nothing for safety. During the whole of its 70 years of existence, not a single preventible explosion stands against the Association. The new Bill, Mr. Stromeyer states, is based upon the hypothesis that legislation is the sole security against boiler explosions, whereas, as the above record shows, there is a general desire amongst factory owners to secure safety. Mr. Stromeyer further points out that Continental countries which started with stringent legal regulation of steam boilers have had to abandon this, and have more and more approximated to the conditions which have hitherto prevailed in this country, and which have secured very great safety in working. Some of the provisions of the Bill are, Mr. Stromeyer states, distinctly dangerous. He objects strongly to the regulation insisting on the provision of fusible plugs which, he states, have proved themselves very inferior to other devices for preventing low-water levels, and which have accordingly been abandoned in tens of thousands of boilers with the most beneficial results. The insistence on the provision of gauge glasses is also objected to, since these are causing a great deal of trouble with high-pressure boilers, and it is probable, Mr. Stromeyer believes, that at no distant date mechanical water level indicators will be used. Moreover, he holds that gauge glass guards are not always advisable. With modern water tube boilers the water gauge is often at a level high above the stokehold floor and the gauge is difficult to read even without the protector, the fitting of which increases accordingly the liability to false readings of the water level. He still more strongly objects to the provision that stop valves shall be attached directly to the boiler, since this arrangement is liable to give rise to serious accidents from water hammer, and the experience of past decades has shown that to avoid steam-pipe explosions due to this cause, the valve should not be placed directly on the boiler, but above the main steam pipe. He states that if this provision becomes law, it will be necessary to alter thousands of existing steam ranges, and that the result will be that steam-pipe explosions will again become frequent. He suggests that other provisions of the Bill indicate that the Home Office attaches far more importance to book-keeping than to the prevention of dangerous practices.

THE IRON AND STEEL INSTITUTE.

The autumn meeting of the Institute is being held this year in London. The proceedings opened on Wednesday evening, the 3rd inst., when the President, Sir William Ellis, supported by the Council, held a reception at Princes' Galleries, Piccadilly. The reading and discussion of papers—of which there are ten in the list—commenced yesterday and is being continued to-day at the British Empire Exhibition, in Conference Hall No. 3. We shall report the proceedings in our issue of next week. We reproduce in this issue, in abstract, a paper by Mr. Marcus A. Grossmann and Mr. Edgar C. Bain, Dunkirk, New York, on "The Nature of High-Speed Steel" (page 347), and we begin publication of a paper on "The Changes of Volume of Steels during Heat Treatment," by Dr. W. Aitchison and Mr. R. G. Woodvine (page 351).

LETTERS TO THE EDITOR.

THE NATURAL RESOURCES OF THE DOMINION OF CANADA.

To the Editor of Engineering.

Sir,—Our attention has been directed to a newspaper report on an article published by you on the "Dominion of Canada at the British Empire Exhibition." We would like to offer our congratulations of the appreciation of this article on the value of the natural resources of the Dominion.

In one part of the article you are quoted as saying, "Much of the silica sand used in manufacturing has to be imported." Whilst this is substantially true, we would like to point out that this is not due to any lack of our resources of silica sand but to the failure of manufacturers to utilise the Canadian raw material. We believe that the value of the deposits of this material in various parts of the Dominion is not fully appreciated, and no doubt the neglect is partly due to the fact that so many of our industries originate from the United States and other countries which already control sources of raw material outside of Canada.

Yours very truly,
G. G. Ommanney, Development Engineer,
Canadian Pacific Railway Company, Montreal.
August 21, 1924.

Low Temperature Carbonisation of Coal.—The Department of Scientific and Industrial Research, Old Queen-street, S.W.1, is prepared to undertake in approved cases tests on plants for low-temperature carbonisation. The objects of the test are to ascertain the quality and quantity of the yields of coke, tar oil, gas and ammonia, the output of the plant, working temperatures, and general ease and reliability of working. No charge will be made by the Department in respect of the tests, but applicants will be required to comply with certain conditions and to sign an agreement embodying the terms on which this offer is made. Forms of application may be obtained from the Secretary, Department of Scientific and Industrial Research, 16, Old Queen-street, Westminster, S.W.1.

METALLURGY AT THE BRITISH EMPIRE EXHIBITION.—VI.

FOR exhibition purposes, copper and its various alloys, have over ferrous metals the great advantage that they permit of a much more brilliant display. Iron and steel exhibits, of a necessity, are of a sombre colour and appeal only to the man in the trade, manufacturer or user, whilst copper and the non-ferrous alloys of the copper series not only appeal to the same class of visitors, but also serve to brighten a whole series of stands. A striking example of this is afforded by the very first visit to the Palace of Engineering, where the Non-Ferrous Metal Trades Joint Exhibit and others of the same nature have a most pleasing effect and light up the whole building.

This joint exhibit contains a very large number of representative products manufactured by the members, to the number of 78, of the seven following Institutions: the Brass and Copper Tube Association, the Brass Wire Association, the Brass and Phosphor-Bronze Fine Wire Association, the Brazed Brass Tube Association, the Cold-Rolled Brass and Copper Association, the Manufactured Copper Association, and the Nickel-Silver Association. The main object has been to illustrate the material from the semi-manufactured state right through to the final products, and the customers of the trades have assisted the associations by sending typical exhibits. Representations of the initial processes of manufacture, such as the making of ingot metals and alloys, of pure copper cake, &c., are not shown, owing to lack of space and in order not to overload a display which is already a most complete one.

Dealing first with copper, there is on the stand a partly-constructed locomotive fire-box, a throat-plate weighing 16½ cwt., a tube-plate with the tubes against it, a vacuum pan having an 8-ft. throat, a depth of 3 ft. and a 4-in. brim, weighing about 16½ cwt., and other pans for use in distilleries and breweries, &c. Among specimens of lighter materials are hot- and cold-rolled copper sections, copper sheathing, tinned copper sheets, acid-cleaned sheets and various handsome copper panels. The display of copper tubes ranges from solid-drawn tubes of 24 in. down to a tube 0·005-in. bore, and includes samples of tubes for locomotives, marine, sanitary and numerous other industrial purposes. A picturesque feature of the stand is the extensive use to which copper has been put in the roofing and guttering of the two small offices, one for the Joint Exhibit Committee's staff and the other for housing scientific exhibits. Copper strip and tape for general engineering and electrical purposes illustrate another application of copper over a wide range. There are, further, a very large number of examples of copper wire, comprising the largest size drums down to spools of 48 I.W.G.

The heaviest brass plate is one for the manufacture of a condenser tube-plate; it measures 10 ft. in diameter and is 1⅛ in. thick; from this the brass exhibits range down to the finest brass foil. An infinite variety of brass work is also shown, the enumeration of which would take up too much of our space; it will suffice for us to state in this connection that the great majority of alloys called for in the light brass trades are represented in this series. A large range of wires in coil for the home and export trades can also be seen, together with a comprehensive series of decorative sections and tubes.

The display of phosphor-bronze sheet covers a range which illustrates all the present uses of this alloy.

The nickel-silver manufacturers have sent sheets and panels, near which are shown their various products manufactured for the home and Eastern markets, including table cutlery and numerous other utensils. The various uses for nickel-silver for electrical purposes are also amply illustrated.

A most important feature of the stand is the exhaustive scientific exhibit made under the joint auspices of the Institute of Metals and of the British Non-Ferrous Metals Research Association, the latter an association established in 1920 for research upon co-operative lines. Very active work has been carried out since and is being continued at the National Physical Laboratory under Dr. W. Rosenhain, F.R.S., the Research Department, Woolwich, under Dr. H. Moore, the Metropolitan-Vickers Electrical Company, Limited, under Mr. R. W. Bailey; the Royal School of Mines, London, under Professor Carpenter, F.R.S.; the Birmingham University, under Professor Turner; the Sheffield University, under Professor Desch, F.R.S.; the Manchester University, under Professor F. C. Thompson, and Mr. A. G. Lobley; and at University College, Swansea, under Professor C. A. Edwards. These establishments have displayed on the stand a number of test specimens, charts, diagrams and printed matter which give an idea of the extent of the research work they have accomplished during the last few years.

Information can also be gathered on the stand concerning the work of the Institute of Metals, a comparatively young body—it was founded in the year 1908—but not the least energetic by any means of all the British technical societies. Its aim has always been to encourage and to increase research and its application to non-ferrous metallurgy in all its branches, an aim which it has hitherto fully met and will continue to meet in the future. The Institute has an exhibit illustrative of its inquiry into the corrosion of condenser tubes. Coloured diagrams show sections of these tubes and of the scales formed upon them in sea water. The diagrams prove that the rate of corrosion of the tubes is mainly dependent upon the property of the scales. A set of diagrams gives the reactions as a result of which the scales are formed. The manner in which scales may break down locally and so give rise to pitting is also illustrated. Actual tubes taken from commercial condensers are shown to illustrate each type of corrosive action. A novel method can be seen for protecting aluminium from the action of sea water, especially under conditions in which the metal is liable to be alternately wetted and dried. The metal is made the anode of an electrolytic bath of special composition in order to give it a particularly thick protecting film of oxide. A remarkable series of specimens is displayed of aluminium protected by this method. A means has been found whereby aluminium can be rendered not only resistant to corrosion but also can be coloured by dyes, this making the metal particularly suited for decorative purposes. There are vast possibilities in store for this new process.

Messrs. Allen, Everitt and Sons, Limited, Smethwick, are included in the joint exhibit above referred to. Close by they have a special stand on which they show brass and copper locomotive tubes; solid drawn brass and copper tubes from ¼ in. to 12 in.; solid drawn brass condenser tubes; square brass tubes for bedstead making; yellow-metal and brass condenser plates. Their display also includes practically indestructible cupro-nickel tubes for land and marine condensers; Bull's "melloid" condenser tubes, acid resisting; brass and copper sheathing sheets, rods; nickel-bronze rods for staybolts for locomotive fireboxes; hollow brass rods which they can manufacture in any required size.

Messrs. James Booth and Co. (1915), Limited, Birmingham, a subsidiary comapny of Messrs. Vickers Limited, exhibit, as a part of the Vickers' show, non-ferrous specimens, embracing brass and copper products in great variety. This company manufacture also the well-known light alloy, "Vickers' Duralumin," in the form of sheets, strips, tubes, wire, rivets, extruded bars and sections, rolled and drawn angles and channels, forgings and drop forgings. The duralumin exhibits are of especial interest as they indicate the many directions in which the alloy is being found to be applicable. These duralumin exhibits include a collection of drop stampings used in the production of the modern light metal artificial limbs; bent tubes, some being circular coils for service as mandrels for the curing of rubber tubes in the tyre industry, &c. A striking display is a collection of drop stampings for motor-car engine connecting rods, indicating the extent to which this alloy has invaded the field of internal-combustion engine manufacture.

This alloy in connecting rods has a tensile strength on an average of 25 tons to 30 tons per square inch, and is replacing steels showing a much higher figure, for practical tests have determined that by altering the design slightly and eliminating sharp corners by the introduction of larger radii, both at the H-section and at its junction with the end bosses, a considerably stiffer rod is produced. The section is also slightly thickened up in some cases, so that the "Duralumin" rod weighs about half the steel rod previously used. A feature which is frequently overlooked in a cursory comparison in this instance is that the stresses induced in the rod, due to its own weight, are naturally considerably lessened in the case of "Duralumin." One of the rods forming part of the exhibit has done over 100,000 miles in a 15·9 h.p. car, and was not specially designed for the purpose, having been produced from the actual dies which served to manufacture the standard steel rods used on that type of car. Speeds of from 4,000 to 5,000 revolutions per minute have been safely attained with the newer design of rods. There are several examples of spinnings and pressings produced from this material, amongst which is a clutch cone pressing, which indicates another promising development tending to reduce the weight of motor-cars. A number of exhibits of articles shown are made by users of this alloy, such as wireless headphone parts, camera parts, racehorse shoes, tennis and badminton rackets.

Another interesting non-ferrous metal exhibit is that of the Delta Metal Company, Limited, London and Birmingham, whose stand is in the central portion of the Palace of Engineering. The business was founded in 1883 by the late Mr. Alexander Dick, who adopted the Greek equivalent of the initial letter of his surname as a trade mark and embodied it in the name of the company formed to work his inventions. It should be noted that "Delta" is not the name of a particular metal; it is applied to a great variety of metals and alloys supplied by the company, principally in the form of semi-manufactured products, such as rods, wire, sheets, forgings, stampings, castings, &c., and covering a wide range, from high-tensile bronzes to ordinary screwing brass, and from white bearing metals to high-conductivity copper. The late Mr. Dick invented in 1894 the process of pressing copper alloys and other non-ferrous metals, at a high temperature, in the form of rods and sections, for which process he adopted the name of "extrusion." This process has greatly assisted the development of trades depending upon the rapid output of repetition work, and has also rendered it possible to produce sections and shapes which could not be made by the older processes of rolling and drawing. As a consequence it has given a very considerable increased scope to the use of non-ferrous metals in constructional work. Extruded rods and sections range from thin wires and shapes to heavy bars, angles, channels and special shapes and sections. They are produced in brass, yellow metal, white metal, naval brass, bronzes, copper, &c., either in special complicated shapes or forms, or as plain round, square, hexagon, flat, &c., in lengths as required.

Various "Delta" bronzes are displayed on the stand. They include acid-proof, corrosion-resisting alloys, high-tensile bronzes, &c., shown in the form of rods and bars, shapes and sections, both solid and hollow; forgings, stampings, pressings and castings; wire, sheet, tubes, &c. "Delta" bronze No. I is the strongest malleable bronze, having about 50 tons tensile strength per square inch. "Delta" bronze No. II (silver bronze) is an improved "German" silver. "Delta" bronze No. III is shown in solid drawn tubes. "Delta" bronze No. IV, the most popular one, is stated to be as strong as steel, as tough as wrought iron, and to have the highest resistance to corrosion. This brand is made in various grades to meet special requirements. It is largely used as a substitute for steel in general engineering, shipbuilding, mining, sanitary and other work, and is supplied in ingots for casting, or as billets for forging, or again in the semi-manufactured state as rods, forgings, sheets, &c. Forgings are made up to 3 tons and over; a number of forgings, pump rods, shafts, &c., form a striking part of the display. "Delta" brand white anti-friction metals are produced in various grades for light and heavy pressures, various speeds, for marine and other

engines. There are "Delta" brand copper high-conductivity bars and sections; bolts and rods for firebox stays, &c. "Dixtrudo" high-speed turning and screwing brass in rods and sections; "Dixtampo" yellow metal bolts, rods, forgings, &c., are also shown in great variety. Test pieces of the various metals and alloys made by the company point to the strength, tenacity and ductility of the various materials, under hot and cold working conditions, and when subjected to tensile stress.

LITERATURE.

Marine Engineering Practice. By ENGINEER COMM. F. J. DROVER, R.N. London: Chapman and Hall, Limited. [Price 21*s.* net.]

THE changes that have taken place in marine engineering practice during the past fifteen or twenty years may be said to have found their fullest expression in the engine room of a modern battleship or passenger liner. There has been witnessed in that short time the advance from reciprocating steam engines to direct driving turbines, and from these again to the geared turbine drive which in its double reduction form has so disturbed the peace of mind of many engineers in recent times; and now the advent of the internal-combustion engine with its return to reciprocating motion bespeaks another change. And as the prime movers have changed, so also have the auxiliaries in sympathy with them. When to these are added the changes due to the increasing use of superheated steam and the substitution of oil for coal as the primary source of power in the boilers, it is easy to realise that there is a greater variety of machinery installations to be met with on the high seas to-day than ever before, and that the machinery compartments of modern vessels are necessarily becoming more and more complex in character.

It is therefore a matter of primary importance that the engine room personnel should have the fullest knowledge possible of the leading features to be met with in the design, construction and working of the costly and oftentimes delicately adjusted machines placed under their control. Apart from the main engines, marine engineers have now to look after many machines and devices of an auxiliary character unknown to their predecessors, all of which have been devised for the more economical working of the ship or the greater safety and convenience of the passengers and crew. Each machine added to a vessel's equipment adds also to the engineers' responsibilities and demands from them greater proficiency and wider experience.

Much interest has always been centred in marine engineering practice. It is a theme that has inspired many writers, and to-day many books and papers are available in which various aspects of the subject are dealt with in more or less detail, yet in view of the rapid changes we have just outlined, it is not surprising that still another book should appear. As the author remarks in his preface, such a book is "only justified" if it "fulfils new requirements or gives new methods not already available in book form." Commander Drover's book is quite evidently the fruit of an experience ripened by many years service at sea, and as such it has its own value, but it labours under some of the disabilities derived from an experience so gained, and falls short of the aim its author sets before him. The point of view in the book is that of the man in the engine room, and whilst throughout its forty-two chapters reference is made to varied practices in design and construction, and divers types of main and auxiliary engines are described, the atmosphere of the engine room pervades all its pages and the practice laid down is that of the man on the starting platform. Reference is made now and again to mercantile practice, and Board of Trade regulations are recognised, yet the practice described is essentially that which obtains in naval vessels. In this respect the book will not appeal widely to the engineer officers of the mercantile marine, notwithstanding that the descriptive matter and the illustrations are largely representative of mercantile practice in design and construction.

In the opening sections of the book, boilers and oil fuel burning are dealt with, and emphasis is rightly laid upon the necessity of giving as great care and attention to the steam generators as is given to the main engine. We agree with the author that more use might be made of the water-tube boiler in the mercantile marine. This type of boiler offers many advantages, and although it may require more skilled attention than the ordinary cylindrical boiler, the higher attainments of the present-day engineer make him more than equal to the task. Among the types of boilers briefly described, we miss any reference to the White Forster type, whilst on the other hand the "up-to-dateness" of the book, which is not very evident throughout its pages, would be helped by the omission of all reference to the Belville, Niclausse and other types which are now almost obsolete, at least in this country. Superheating as applied to water-tube boilers is lightly touched upon, and the general statement is made that superheating "has not been extensively applied in this country to marine work." This is scarcely in accord with present-day practice in this matter, and one wonders if the author has heard of the smoke tube type of superheater so commonly fitted to cylindrical boilers in the mercantile marine, as it is not even mentioned in the book.

In the two short chapters dealing with oil-fuel burning there is guidance given on how to deal with a small fire, but we should like to have seen more emphasis laid upon the precautions to be taken against the outbreak of fire. These chapters scarcely do justice to a subject which to-day is becoming increasingly important.

In those sections dealing with reciprocating marine engines and marine turbines, the author follows usual lines, but has not been too happy in his choice of representative types. Emphasis is very properly laid upon the importance of close attention being given to the forced lubrication system in turbine installations, past experience having shown that many cases of blade stripping could be traced to a failure of the oil supply to the rotor bearings. A chapter is devoted to the Michell type of thrust block, and its advantages over the multi-collar type of block are emphasised. It is not brought out, however, that the Michell block is equally suitable for use with reciprocating engines and turbines. It would appear also that the author had some special design of block before him when writing his description, as otherwise we cannot understand his reference to hardened steel balls. These are not to be found in the normal design of Michell block, nor do they appear in the illustrations which accompany the text.

The importance of a high vacuum in turbine machinery installations is well understood and appreciated by engineers in general, and this subject is considered in Parts V and VI, where condensers and their kindred auxiliaries are described. We miss, however, a due appreciation of the part taken by the circulating pump in producing and maintaining a high vacuum. This is a very important unit in the combination of parts which go to make up a condensing plant, but it gets no more than passing mention in one or two places throughout the book. The "Contraflo" specialities are fully referred to, and some other well-known makes of auxiliaries calling for no special comment, are illustrated and described. The question of corrosion of condenser tubes, that bugbear of the sea-going engineer's life, is referred to, along with the twin question of corrosion in boilers, in an early chapter in the book, and the various electrolytic and other means generally adopted to overcome the trouble are considered. The trouble, however, is a persistent one, and not easily overcome when once it starts.

That section of the book dealing with the internal-combustion engine is in many respects the most up to date. It is, however, almost entirely devoted to descriptions of various well-known makes of heavy oil engines, as fitted in the mercantile marine, and to that extent is limited in its usefulness, as a book of reference, to the sea-going engineer. No attempt is made to enumerate or contrast the points for and against the two and four-stroke cycle types of engines, which, in view of the controversial nature of the subject and having regard to the present state of development of the oil engine in general is doubtless quite wise; but one misses in the opening chapter of the section an outline description of the principles of operation of the opposing cycles. The air pressure system of fuel injection is briefly described, but some consideration is due to the alternative solid or airless injection system, the merits of which are now obtaining wider recognition in the oil engine industry; and more particularly so, as two of the engines described in the book employ that system of fuel injection. Many heavy oil engines suffer from the disability of bad air scavenging, hence the importance of good scavenging in the sure and economical running of oil engines in general, and of two-stroke engines in particular, cannot be over-estimated, and the author might have made much more of this aspect of the subject.

The Diesel engine is termed a constant-pressure engine, not because "the fuel injected into the cylinder is under a pressure which is much higher than the pressure in the cylinder itself," as the author states, but because the fuel is burned in the cylinder at a constant pressure over a definite period of time, as opposed to a constant volume or explosion engine, in which the fuel is burned almost instantaneously, and is accompanied by a marked rise of pressure in the cylinder. In neither case does the pressure of injection of the fuel affect the question.

The last two chapters take up questions concerning adjustments and repairs to machinery parts, which should prove interesting to the student of engineering who may be contemplating a seafaring career. There is a tendency here and there throughout the book towards repetition, and some slips are to be noted, as, for example, in the last chapter, where the operations involved in the fitting of a new ring to a large low-pressure piston are carefully described. When, however, the operations are completed, the reader discovers that the new ring has been left out.

The book is well printed on excellent paper and the illustrations are numerous and distinct.

Chemistry of the Rarer Elements. By B. SMITH HOPKINS, Professor of Inorganic Chemistry, University of Illinois. London: G. J. Harrap and Co., Limited, 39-41, Parker-street, W.C.2. [Price 15*s.* net.]

WHEN we reviewed two books on the rarer elements four years ago, we pointed out that the term "rare or rarer elements" survived merely as a matter of convenience. The fact was quite admitted by the authors of those two volumes, Dr. W. R. Schoeller and Mr. A. R. Powell, on the analysis of minerals and ores of the rarer elements, and Dr. J. F. Spencer on the rarer earths. The years which have elapsed since then have only brought additional evidence that some of these elements are much more widely, though hardly more abundantly, distributed than had been thought. Yet the term persists, and we find that Professor Hopkins, in his "Chemistry of the Rarer Elements," deals with lithium, tungsten and vanadium, the platinum metals and tellurium under this heading as chemists would have done half a century ago. But Professor Hopkins adds the rare and noble gases, which had generally been kept apart, and also radium to his treatise, and he opens it by a chapter on the periodic table. The primary reason for the additions seems to be that Professor Hopkins, like his collaborator, Dr. C. W. Balke, has been giving a course of lectures on the periodic table with special reference to the rare elements, about some of which his students would in vain consult their text-books.

The additions are quite appropriate. The noble gases occur only in the atmosphere and in some volcanic exhalations and mineral waters. They form a natural group of their own, the zero group of Professor Hopkins, and while standing by their chemical inertness and electrically-neutral character between the active electro-positive and the electro-negative elements, each of these gases, with its closed rings of electrons, is considered to be characteristic of the other elements of the same row in the periodic table. If they have no valency electrons, and therefore no chemistry—the argument might be reversed—they claim considerable attention from the physicists. The laboratory uses of helium, neon and argon are well known. Of argon, Professor Hopkins states, the incandescent amp industry of the United States required 70,000

cub. ft. per month by the end of 1922; krypton and xenon have not yet found applications, partly because they are really very rare. But many of the other rare elements are distinguished by valuable properties, and it is owing to these that they have been searched for and ceased to be rare.

In his volume Professor Hopkins characterises each group of his elements, and then proceeds to outline the history, occurrence, separation and metallurgy, purification, properties, compounds and uses of each particular element. He thus covers the general ground which Schoeller and Powell had had to leave to others, and he does this well in his 376 pages. We see that rubidium is utilised only in micro-chemistry because it readily forms crystalline compounds, that a gallium-cadmium alloy makes a good monochromatic vapour lamp and that indium, which like gallium occurs in traces in certain zinc ores, has no uses at all as yet. Professor Hopkins mentions that lumps of metallic beryllium were last year obtained at the National Physical Laboratory, that hafnium seems to be the missing element of atomic number 72, and that tellurium, already utilised as a ceramic colouring agent, in photography, and as a crystal detector in radio-telegraphy, is, in the form of one of its volatile compounds, also added to gasoline to prevent knocking in high-compression motors. Nor does he forget to point out that the compound in question, diethyl telluride, like some other tellurium compounds, has a vile smell which almost poisons the experimenter and the atmosphere he carries with him, for many days. How horrible this may become was only established last year. Professor Hopkins should not have omitted, however, to put the names glucinum (the element more generally known as beryllium) and niobium (otherwise columbium) in his index, which is too short; he gives the history of the identification of these elements, which received different names by different investigators and are still apt to be confused. But what he says on the alloys of the rare elements and on the rare earths is all very readable, and he has made a valuable contribution to the collective literature on the subject.

Electrical Measuring Instruments. Part I. *Commercial and Indicating Instruments.* By C. V. DRYSDALE, O.B.E., D.Sc., and A. C. JOLLEY, A.M.I.E.E. London: Ernest Benn, Limited, 1924. [Price 55*s.* net.]

THE title of this book fails to convey an adequate idea of its varied contents, or to indicate the full purpose contemplated by the authors who have considered the construction and performance of direct indicating electrical instruments on very exhaustive principles. They have aimed at presenting a very full picture of the gradual development of a particular class of instruments, of illustrating the growth of accuracy, of showing how sources of error have been eliminated, and advantage taken of alternate methods for measuring the effects produced by the phenomenon under examination, and so of securing independent control. But though historical and philosophical details connected with construction add to the interest of the volume, the main purpose is intensely practical, and is directed to giving the user technical information of the varied types of instruments. These have been purchased from the makers, or obtained from them with the full knowledge that they would be submitted to a critical and independent examination, for the results of which the authors accept full responsibility. This unbiassed attitude increases the value of the treatise and removes some of the features which occasionally disfigure descriptive works of this character.

An introductory chapter explains the general electric principles underlying instrument construction, and indicates how certain observed effects, whether magnetic, thermal or chemical, can be utilised to determine quantitative measurement. It is a long step from Faraday, a century ago, to Einthoven, from Davy to Duddell, or from the early observers of the effects of electrolysis to those of to-day, but the continuous path of progress is distinctly shown by well distributed signposts. To trace the effect of growth of mechanical accuracy on the history of inventiom, to perceive how design has been altered by theoretical enquiry, and, perfected by experience, to trace the modifications introduced by new and better adapted materials, is to produce a tale of great fascination and of equal encouragement. The authors regret the incompleteness of their work, for while it has been preparing for press new developments have been announced, that have not of necessity been included. But this is inevitable where progress is continual, and at no time could such a work have been produced in which the latest outcomes of science could have found adequate place. Details, as exhibiting ingenuity are intensely interesting to the expert, but it is perhaps more instructive to linger over the principles that have guided development, to see how the thought suggested by experiment in the laboratory grows into a formula, eloquent of future possibilities, and finally assumes a tangible form and becomes an article of commerce. So, among other instances, we can see Kelvin's attracted disc electrometer taking concrete shape from the suggestions of Snow Harris, and learn how theory has improved on experiment, as clearly as we can see how tools of better design have encouraged delicacy and refinement.

It is not possible to give any details of the dynamometer ammeters, voltmeters, wattmeters, or hot wire indicating instruments, to discuss the principles of their construction or to compare the relative merits of the ingenious devices that have been contrived, details of which naturally occupy a large portion of this volume. Only very imperfectly is it possible to mention, certainly not to discuss, some of the principles that are common to instruments of this class, the sources of error to which they are subject, and the mechanical means applied to reduce error to a minimum.

An indicating instrument consists of two parts, or systems, moving relatively to each other, the moving part bearing some definite and constant relation to the quantity measured, always repeating itself under similar conditions. This implies that such uncertain effects as those arising from mechanical friction, heating, magnetic hysteresis should be as small as possible, while critical damping of the motion may be necessary. The reduction of mechanical friction is entirely a matter of correct design and depends upon the correct application of supporting the moving parts, either by pivoting and suspension, or by knife edge, or by filar support. In passing, attention may be called to the enormous pressure that may have to be sustained at the point of contact of a finished pivot in a jewel cup. A ton to the square inch is a moderate estimate, and in some forms of instrument the pressure is much greater, approaching perilously near the accepted values for the compression strength of steel. Photomicrographs of a set of variously shaped pivots taken from modern indicating instruments are very suggestive. A similar picture of pivot and jewel that has survived more than 200×10^6 oscillations shows what can be effected by this form of appliance. Knife edges and filar suspension are more limited in application, and suitable metallic suspension may be difficult. The authors mention a form of ductile tungsten which has excellent qualities for the purpose of suspension and is very strong.

Damping is a contrivance to compel the moving system to take up its position of equilibrium under the influence of the deflecting forces, without oscillating or overshooting the point of indication. In so-called "aperiodic" or "dead beat" instruments, it is usual to carry the damping just short of the critical condition, experience having shown that the required sharpness of reading is best attained by this means. Air friction, fluid friction, and eddy currents are the usual forms of damping applied. In employing fluids, the choice of a suitable material is important, and the authors favour a mixture of pure paraffin and kerosene, the graphs showing a rapid rise in damping when equal amounts of these oils are mixed. Eddy current or magnetic damping, very effective when it can be used, depends on the reaction of induced currents set up in a moving conductor with the field producing them. The conditions that ensure promptitude of indication are of great importance, and an entire chapter is devoted to the subject, the elements of electrical theory and design claiming another. The reader should, therefore, be fully prepared to follow the very critical and technical descriptions of the various types of instruments discussed. Here, at the hands of competent masters, he will learn much of the theory of instruments, the reasons for following certain forms of procedure, the grounds for the maintenance of certain types, the defects that are remediable and the improvements that have been made

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The Engineering Index, 1923. New York: The American Society of Mechanical Engineers. [Price 7 dols.]

The Depths of the Universe. By GEORGE ELLERY HALE. New York and London: Charles Scribner's Sons. [Price 7*s.* 6*d.* net.]

University of Illinois. Engineering Experiment Station. Bulletin No. 142. *An Investigation of the Fatigue of Metals, Series of* 1923. *A Report of the Investigation.* Urbana, Ill.: University of Illinois. [Price 45 cents.]

Masters of Science and Invention. By FLOYD L. DARROW. London: Chapman and Hall, Limited. [Price 10*s.* 6*d.* net.]

Coal and Oil Fired Boilers. By Eng. Comm. E. J. DROVER, R.N. London: Chapman and Hall, Limited. [Price 16*s.* net.]

Elasticity and Strength of Materials Used in Engineering Construction. Section IV. *Columns. Elastic Theory and Economic Design and Analysis of Eye Bars, Pin and Rivet Connections.* By C. A. P. Turner. Minneapolis: C. A. P. Turner. [Price 5 dols.]

Department of Overseas Trade. Report on the Financial, Commercial and Economic Conditions in Roumania, March, 1924. By ALEXANDER ADAMS. London: His Majesty's Stationery Office. [Price 2*s.* net.]

Uber Diesel-Elektrische Lokomotiven im Vollbahnbetrieb By Dr. Ing. HERBERT BROWN. Zurich: Ernst Waldmann.

United States Department of Commerce. Simplified Practice Recommendation. No. 3. *Metal Lath.* [Price 5 cents.]. No. 7. *Face Brick and Common Brick.* [Price 5 cents.] No. 10. *Milk and Cream Bottles and Bottle Caps.* [Price 5 cents.] Washington: Government Printing Office.

Matter and Change. An Introduction to Physical and Chemical Science. By W. C. D. WHETHAM, M.A., F.R.S. Cambridge: University Press. [Price 7*s.* 6*d.* net.]

Department of Overseas Trade. Report on the Economic Situation of Denmark. April, 1924. By R. M. A. Turner, O.B.E. London: His Majesty's Stationery Office. [Price 2*s.* net.]

British Oil Engines. A Practical Handbook for Attendants, Erectors and Purchasers. By W. A. TOOKEY, M.I.Mech.E. London: Percival Marshall and Company. [Price 2*s.* 6*d.* net.]

United States Bureau of Standards. Scientific Papers. No. 484. *Preparation and Properties of Pure Iron Alloys.* IV. *Determination of the Critical Ranges of Pure Iron Carbon Alloys by the Thermoelectric Method.* By J. F. T. Berliner. [Price 5 cents.] Technologic Papers. No. 252. *The Nick-Bend Test for Wrought Iron.* By HENRY S. RAWDON and S. EPSTEIN. [Price 10 cents.] Washington: Government Printing Office.

Machine Design. Drawing-Room Problems. By C. D. ALBERT, M.E. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Limited. [Price 15*s.* net.]

United States Department of Commerce. Simplified Practice Recommendation. No. 8. *Range Boilers and Expansion Tanks.* [Price 5 cents.]. No. 12. *Hollow Building Tile.* [Price 5 cents] Washington: Government Printing Office.

Motor and Carriage Painting. A Practical Manual. By A. BATES. Second edition, revised and enlarged. London: The Trade Papers Publishing Company, Limited. [Price 6*s.* net.]

The Specific Heat of Gases. By J. R. PARTINGTON, M.B.E., D.Sc., and W. G. SHILLING, M.C., M.Sc. London: Ernest Benn, Limited. [Price 30*s.* net.]

Cosgrove's Hand Book of Woodworking Machinery. Owosso, Michigan: The Cosgrove Company.

Small Houses for the Community. By C. H. JAMES and F. R. YERBURY. London: Crosby, Lockwood and Son. [Price 31*s.* 6*d.* net]

Vorträge aus dem Gebiete der Hydro-und Aerodynamik. Edited by Th. v. KARMAN and T. LEVI-CIVITA. Berlin: Julius Springer. [Price 3·10 dols.]

Where to Seek for Scientific Facts. By ALEC B. EASON, M.A. London: S. Rentell and Co., Limited. [Price 1*s.* net.]

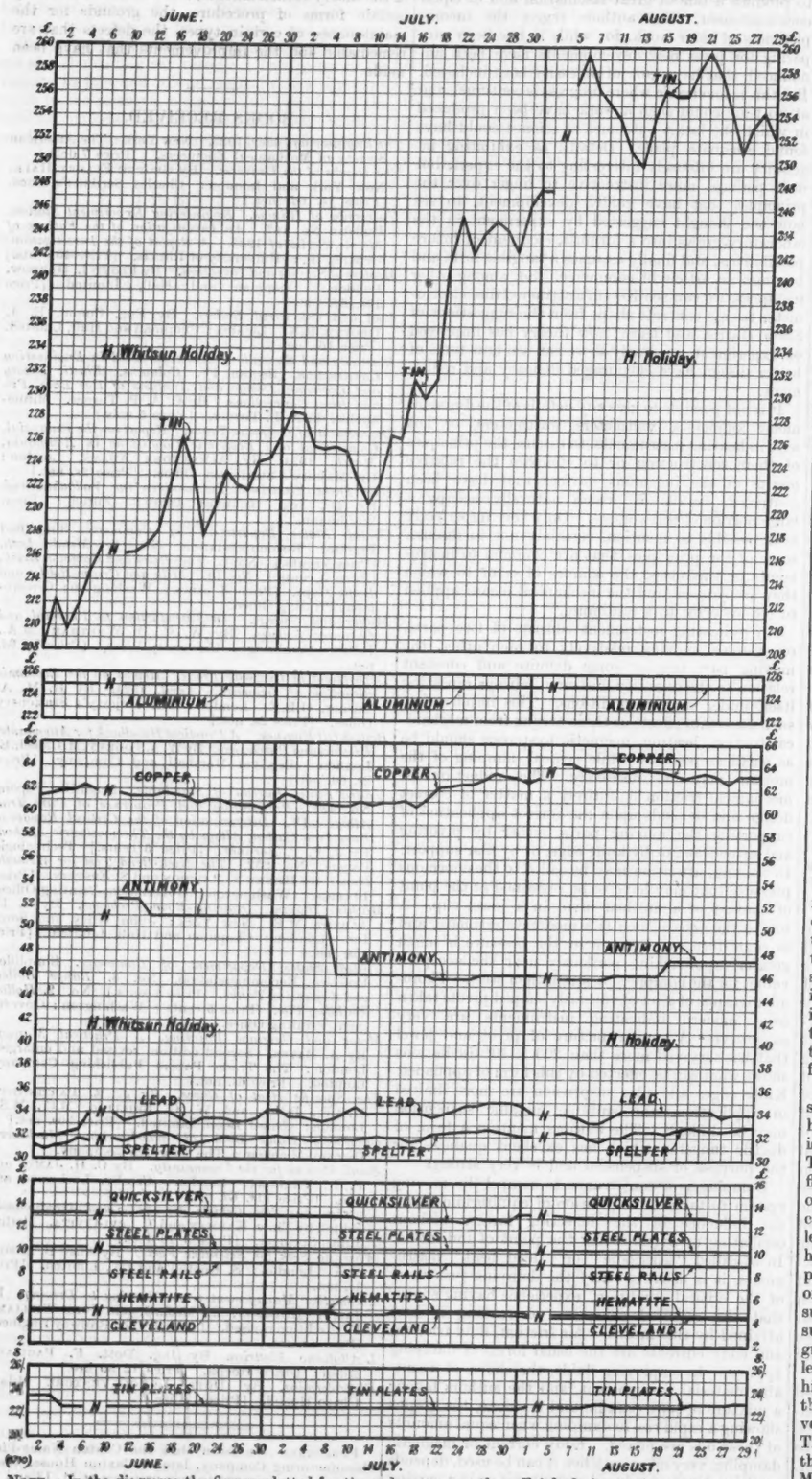
Locomotive Management from Cleaning to Driving. By JAS. T. HODGSON, M.I.Mech.E. and JOHN WILLIAMS. Fifth edition revised. London: The Railway Engineer. [Price 5*s.* net.]

L'Altoforno Elettrico. By Ing. Dott. F. PAGLIARO. Milan: Ulrico Hoepli. [Price 12·50 lire.]

Elettrotermica. By DOTT ROMOLI-VENTURI. Milan: Ulrico Hoepli. [Price 15 lire.]

PERSONAL.—We learn that the Caxton Name-Plate Manufacturing Company, late of Caxton House, Westminster, have removed to new premises at 11, 13 and 15, Rochester-row, Westminster, London, S.W. 1.—We are informed Mr. J. Ferguson, late Chief Engineer of the Glasgow Corporation Tramways, has been appointed to represent the Messrs. Scholey Construction Company, Limited, in Scotland, in connection with their Sandberg "Insitu" rail-hardening process.—We note that on and after September 29 the address of the Belgian Chamber of Commerce in London, Incorporated, will be changed from 24, St. Dunstan's Buildings, St. Dunstan's-hill, E.C. 3, to 8 Union-court, Old Broad-street, London, E.C.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of quicksilver is per bottle, the contents of which vary from 70 lbs. to 80 lbs. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

(*Continued from page* 252.)

WHEN brought to the surface, the full tubs are released and pushed out of the cage by the incoming empty tubs, assisted by the down grade on which the track is laid, a gradient that is uninterrupted when the cage is at the top. With a Westinghouse plant, the use of a power-operated track ram expedites the exchange of empty for full tubs at the pit bank, and gives some initial velocity to the full tubs in the direction of the weighbridge. The arrangement of the surface plant is shown in Fig. 1 of our first article of the colliery on page 678 of the last volume.

The tubs or trams when released from the cage, run by gravity down a slight incline to the tram weighbridge. The tubs are stopped singly on the weighing platform, which is fitted, like the rest of the plant, with rails of 2 ft. gauge. The weighing machine, the indicating portion of which is enclosed in the weigh-house, is of the Avery non-oscillating, automatic, self-indicating type, by which the actual net weights are indicated automatically by a pointer. In order to adopt this method, it is necessary that all trucks should be balanced to the same tare weight, thus enabling the actual net weight of the coal alone to be indicated. It is usual with this type of machine to arrange for a minimum weight to be balanced on the steelyard, and for the quadrant to indicate variations up to 5 cwt. over the minimum. The range of weighings on the quadrant can be altered to suit the requirements of any particular case.

The machine, installed by Messrs. W. and T. Avery, Limited, of Soho Foundry, Birmingham, is actually capable of carrying 5 tons, and has a platform 4 ft. by 3 ft. 6 in., the indicator having a net range of 10 cwt., with 14 lb. divisions, and a tare range of 10 cwt., also with 14 lb. divisions. The net steelyard is graduated from zero to 35 cwt. by 14 lb. divisions.

The pit tubs are of pressed mild steel, with oak underframes, carried on toughened cast-steel wheels 10 in. diameter, secured on 1½-in. axles by the "lock-fast" method of Messrs. Hadfield, Limited, of Sheffield. Various types of tub are shown, some being fitted with Rowbotham's self-oiling arrangement, and others with roller bearings. It is worthy of notice that roller bearings were in use on tubs in the United States and Mexico some years before the war, and that there has been considerable conservatism in their introduction into pit rolling-stock in Britain. Pit trams are also exhibited of the type in general use in South Wales. Tub controllers, of the Wilde and Petrie improved design, which check the tubs and allow them to pass one at a time, also form part of the exhibit.

The greasing of the tub axles has hitherto been a source of waste in collieries, and a special appliance has been designed for this by Messrs. Hadfields, and is known as the "Hecla" automatic tub greaser. This consists of a cast-iron trough made with a flange at each end to rest on the sleepers, the body of the trough being buried in the track. A cast-iron corrugated wheel, kept in a vertical position by the lever in which it revolves, is arranged at such a height that it is depressed by the axle of the tub passing over it, which engages with the corrugations on the wheel, causing it to revolve and bring up sufficient grease for the efficient lubrication of a succeeding axle. The internal arrangement of the greaser is such that it can be changed from right to left hand by taking off the lid and removing the hinge pin. The lid, wheel, lever, and collars may then be turned completely round and replaced, converting the appliance to one of the opposite hand. The lid is so arranged as to prevent dirt getting into the trough. Amongst other gear exhibited by Messrs. Hadfields is a range of haulage rollers and pulleys, complete with their frames and stands constructed of best toughened cast steel.

The full tubs, after being weighed, pass to the special creepers (Figs. 126 to 130, page 339) for raising the tubs up the incline to the top of the staging on which the rails are brought to the tipplers, as shown in Figs. 126 to 129. The empty tubs, after passing through the tipplers, are shunted and

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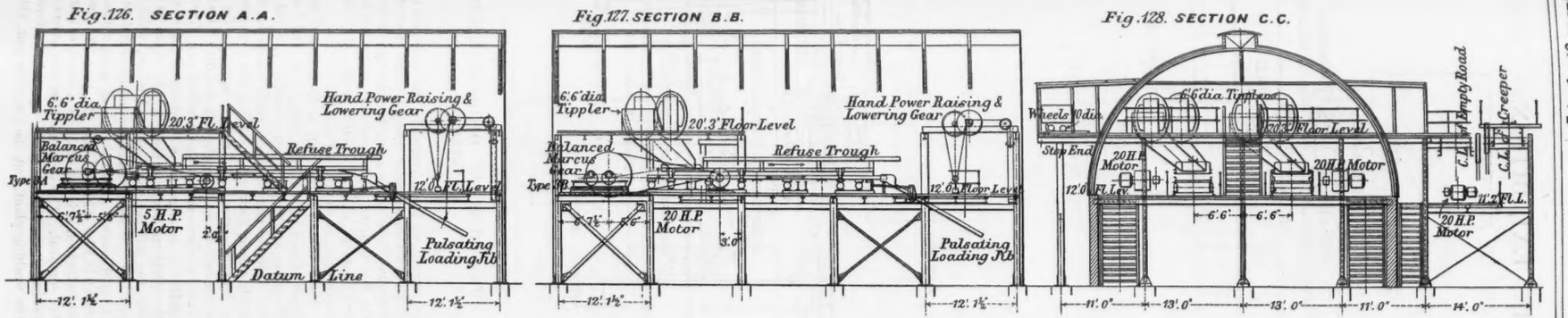
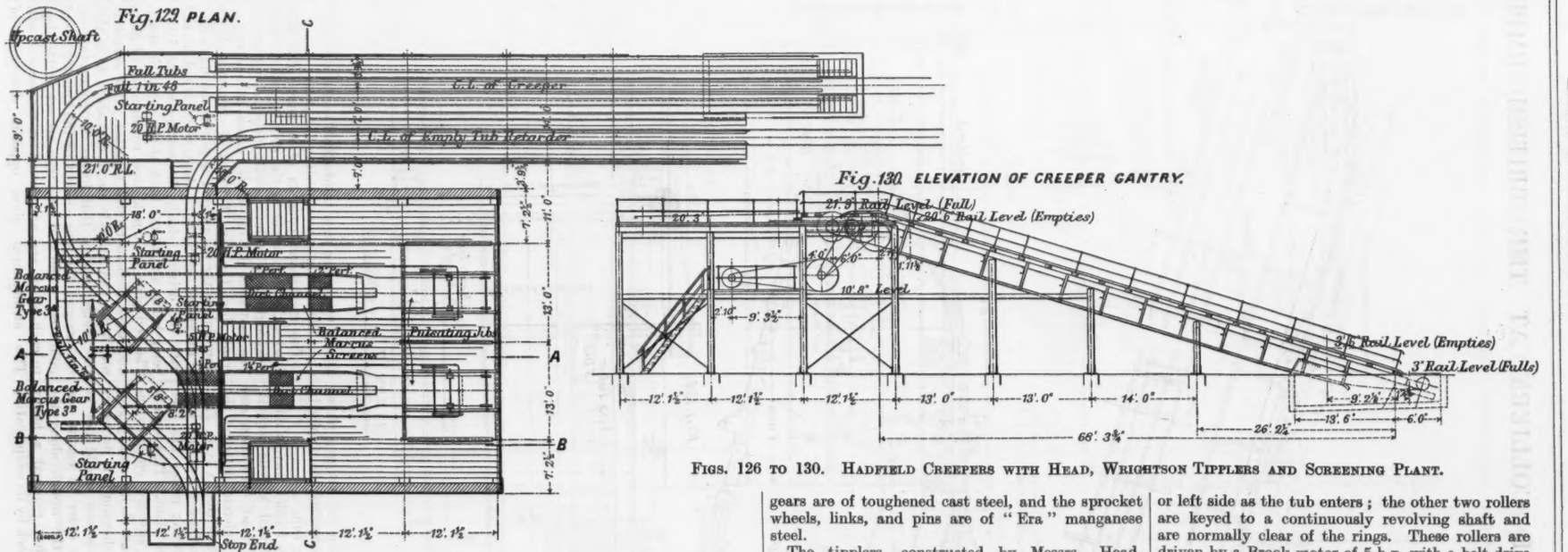
Fig. 126. SECTION A.A.





FIGS. 126 TO 130. HADFIELD CREEPERS WITH HEAD, WRIGHTSON TIPPLERS AND SCREENING PLANT.

returned to the pit mouth by means of a second creeper, which is actually an empty tub retarder. These creepers, constructed by Messrs. Hadfields, Limited, of Sheffield, are shown in greater detail in Figs. 131 to 135 on page 340; they have a gradient approximately 68 ft. in length, with an incline of 1 in 3¼, and are run at a speed of 66 ft. per minute. The up and down creepers are of similar construction, but there is a modification in the form of the driving dogs, which are flat faced, as shown in the larger scale drawings, Figs. 133 and 134, in the case of the rising creeper, and are hook-shaped for receiving the empty tubs on the descending creeper. The dogs are spaced at intervals of 10 ft. on the rising creeper and 6 ft. on the descending creeper. The creepers are driven by a 10-h.p. Brook motor, with belt drives to the first and second reduction shafts and spur gear for the third reduction to the tumbler shafts, which revolve at a speed of 11 revolutions (or 66 links of the creeper chain) per minute. The gears are of toughened cast steel, and the sprocket wheels, links, and pins are of "Era" manganese steel.

The tipplers, constructed by Messrs. Head, Wrightson and Co., Limited, of Stockton, consist each of two cast-iron rings connected by angles and plates riveted together with deflector plates above the tub to prevent spilling endways when the tub is inverted. The tub runs into the tippler on continuations of the rails riveted to the lower of the tippler frame angles; an upper pair of angles retains the tub in place during the tipping operation. The rings are carried on four rollers (not shown in the illustrations); two of these are idle and run on a shaft supported below the "front," or left side as the tub enters; the other two rollers are keyed to a continuously revolving shaft and are normally clear of the rings. These rollers are driven by a Brook motor of 5 h.p. with a belt drive to the first reduction shaft, which carries a bevel-pinion gearing into a bevel wheel keyed to the "back" roller shaft. Two curved wedging pieces, having surfaces adjustable by means of set screws and retaining bolts, and terminating in a stop, are secured to the rings, and engage with sliding top blocks operated by a hand lever. On lifting the lever the stop blocks are withdrawn from the wedging pieces, thus enabling the rings to drop about $\frac{1}{16}$ in. into contact with the driven roller shaft, which performs the tipping, and at the

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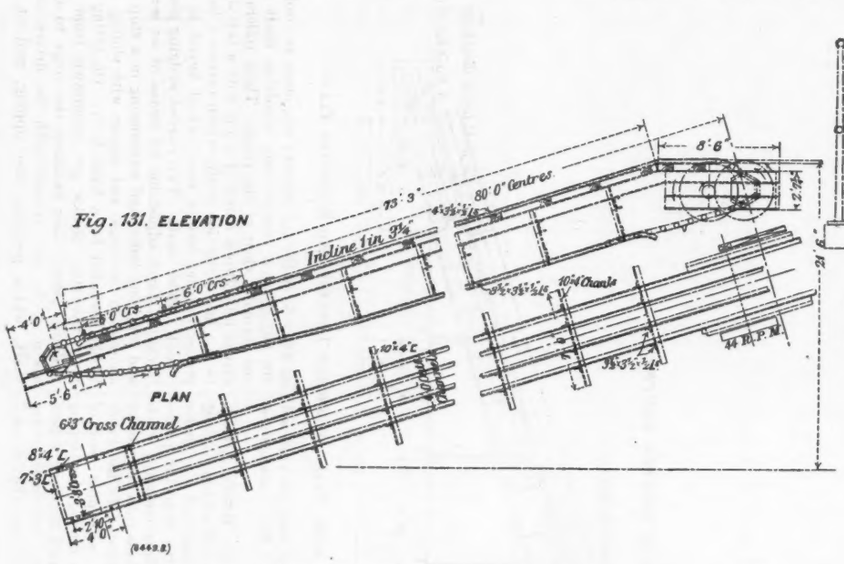
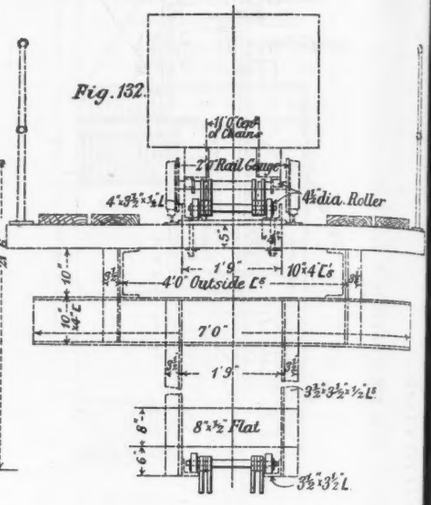
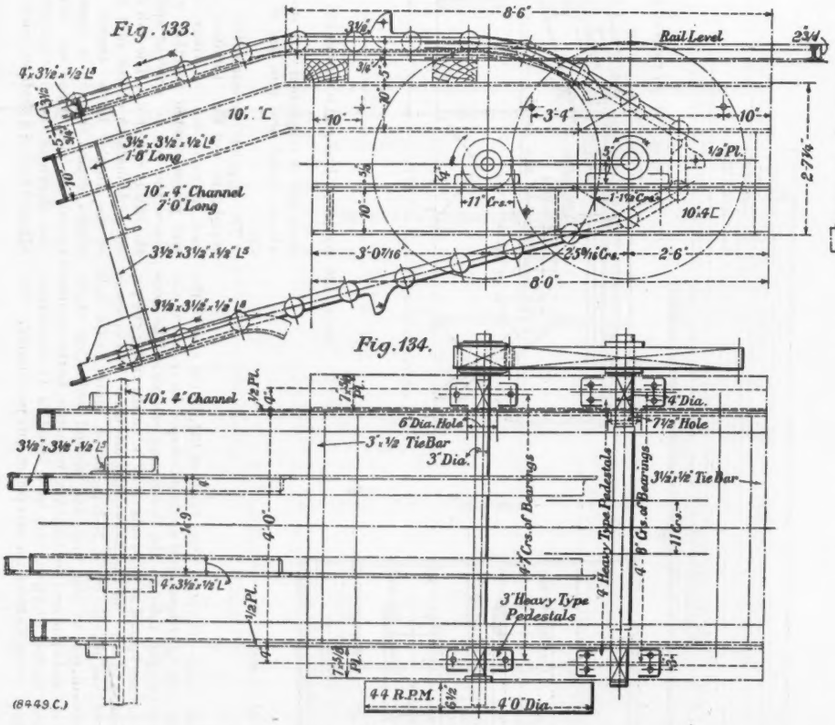
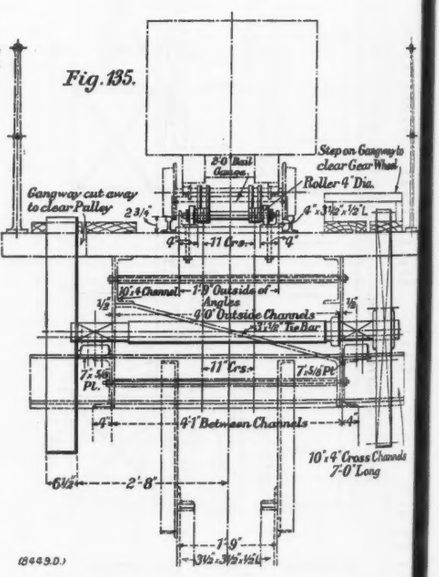








FIGS. 131 TO 135. DETAILS OF HADFIELD CREEPERS.

end of the complete revolution the wedging pieces come into action, lifting and locking the tippler in readiness for the succeeding tub.

The coal tipped from each tippler travels down a shoot to one of two balanced Marcus screens, also constructed by Messrs. Head, Wrightson and Co. The screens are of two different patterns, the one nearest the creeper being of the 3A type, Figs. 136 to 139, page 341, absorbing about 13 h.p., though actually a 20-h.p. Brook motor has been installed for uniformity in the plant. This form of screen constitutes a great advance on previous screening practice using plate belts and jigging screens. In this class of mechanism it is necessary that the propulsion of the screen should not be harmonic, but irregular, in order to ensure the travel of the material in the trough along the screen. In the past this has required a heavy propulsion gear producing shock by its reciprocating action, which has been transmitted to the structure or, to the foundation supporting the gear.

The mechanism consists of a heavy cast-iron flywheel, which serves as the driving pulley, with a wrought-iron pulley usually fitted alongside it. The cast-steel driving shaft carries at one end a crank disc, the pin of which is connected by a drag-link to the corresponding pin on the crank disc at the end of the eccentric shaft, which is not coaxial with the driving shaft, the setting of the latter being below and to the back of the eccentric shaft. The bed plate is of mild steel constructed of plate and angle sections riveted together. The eccentric rod, strap and knuckle are of cast steel, as is also the bridge bracket that forms the connection on the trough; the pins connecting the knuckle are of mild steel. The two eccentrics are set at 180 deg. to each other, and are carried on the same shaft. This arrangement gives opposite directions of movement to the material in the upper and lower of the two superposed troughs. The effect of the drag-link is to cause a much more rapid motion in the last quarter of the outward stroke and in the first quarter of the inward stroke, the velocity curve being as shown in Fig. 140.

Each trough carries up to four sizes of screen, those shown in one case being 2 in. and 1 in. in diameter, and in the other machine 1½ in. and ½ in. The troughs run between guide rollers for maintaining their horizontal position, and a combination of tension springs and rollers, shown in Fig. 145, opposite, ensures that they do not lift off the horizontal surfaces on which the rollers run. The table surface is arranged at a comfortable height above the platform for the pickers, who stand on each side for picking the rock and refuse, which they put into the small auxiliary refuse trough or dirt channel carried above the upper main trough, and shown in Figs. 126, 127 and 129, page 339, from the end of which it is delivered by a conveyor to trucks for removal. The delivery from the screens is in ordinary conditions taken by belt conveyor to the washing plant, but the conveyor gear, which is

THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION; BALANCED SCREEN.

CONSTRUCTED BY MESSRS. HEAD, WRIGHTSON AND CO., LIMITED, ENGINEERS, THORNABY-ON-TEES.

Fig. 136.

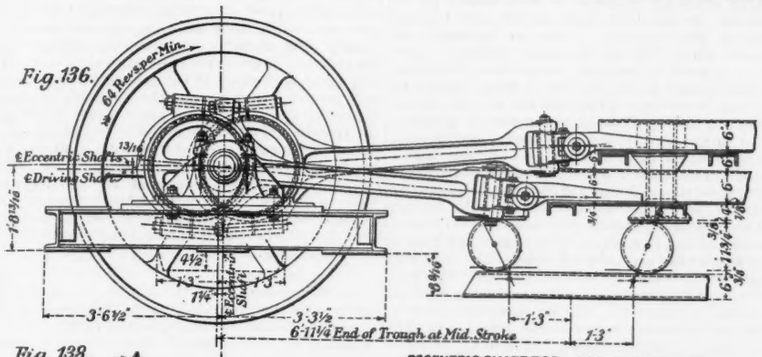


Fig. 137. SECTION ON LINE A.A.

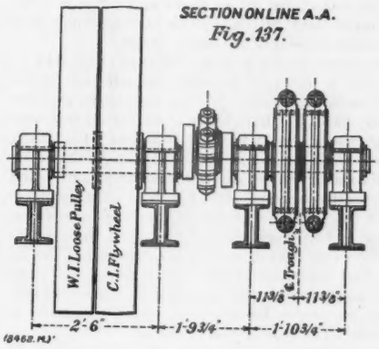


Fig. 138.

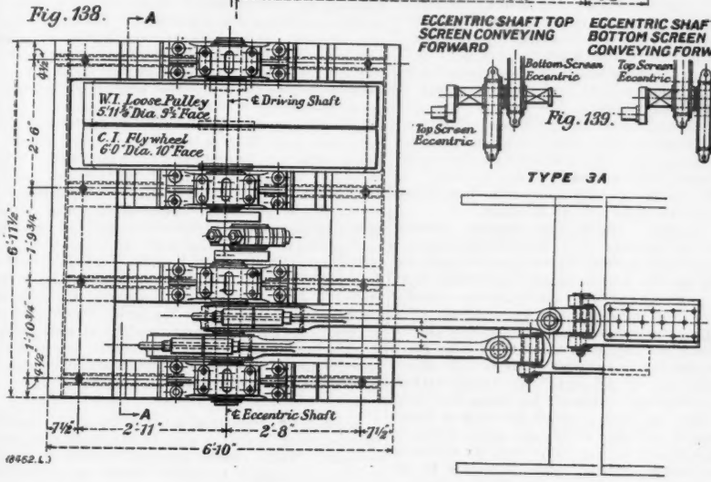
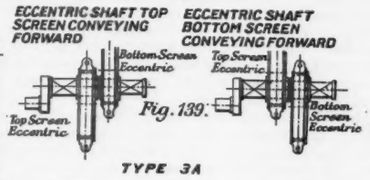


Fig. 139.


ECCENTRIC SHAFT TOP SCREEN CONVEYING FORWARD
ECCENTRIC SHAFT BOTTOM SCREEN CONVEYING FORWARD
Bottom Screen Eccentric
Top Screen Eccentric
Top Screen Eccentric
Bottom Screen Eccentric

TYPE 3A

Fig. 140.

Velocity Curve for Crank and Long Connecting Rod ------
Velocity Curve for Balanced Marcus Screens ——

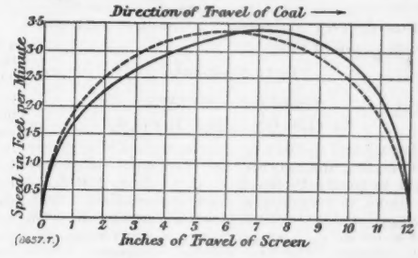


Fig. 141.

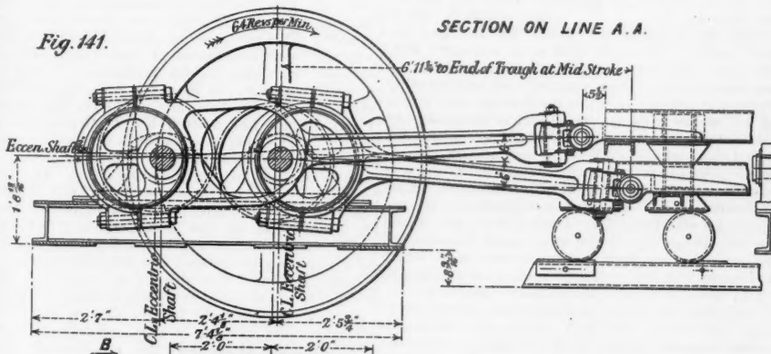
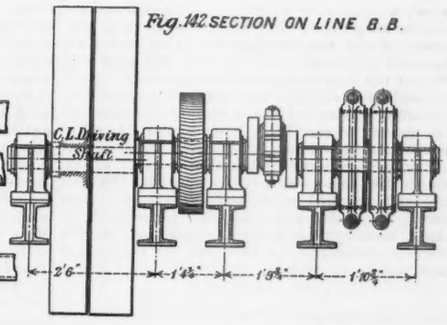


Fig. 142. SECTION ON LINE B.B.



TYPE 3B

Fig. 143.

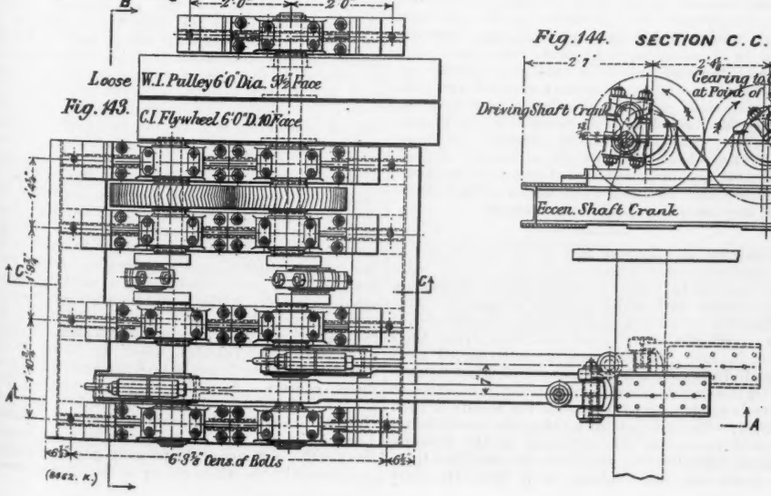


Fig. 144. SECTION C.C.

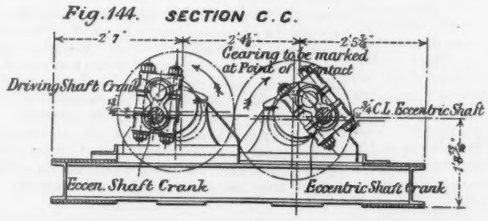
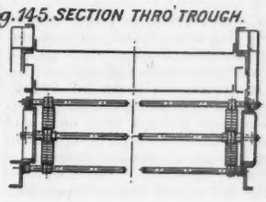


Fig. 145. SECTION THRO' TROUGH.



usually arranged to suit the lay-out of the particular plant, has not been fitted on the exhibition plant. Each trough is 12-in. stroke, driven at 64 revolutions of the eccentric shaft per minute. The 3A type of balanced Marcus screen is capable of screening 100 tons per hour, the large and best coal passing direct to the railway truck down the pulsating jib, suspended at its lower and outer end by wire ropes and driven by connecting links and slides from the end of the lower trough.

The second screen is of the 3B type, Figs. 141 to 145, and is arranged for both troughs to deliver in the same direction. In this case there are two driving shafts, the drive being by machined cast steel helical gears, shown in Figs. 142 and 143. Each driving shaft is connected by a drag-link to its non-coaxial eccentric shaft, the arrangement being shown in the sectional view, Fig. 144. The eccentric rod of the further eccentric is made of open form, so that it can work clear of the shaft that carries the eccentric that is nearer the troughs. The 3B type has the same stroke and runs at the same speed as the previously described 3A type; it takes about 26 brake horse-power, and is capable of screening 150 tons of coal per hour.

A third (C-type) machine is also constructed by Messrs. Head, Wrightson and Co., and has the two horizontal screens arranged side by side. The large surface of the screens in all the three types and the manner in which the coal is spread thinly over the surfaces greatly assists the hand-picking operation, and ensures the elimination of small coal and refuse and the delivery of the best coal into the truck with the minimum of breakage.

(To be continued.)

NOTES ON NEW BOOKS.

ADVANCE in spectroscopy, in the fields of both theory and research instruments, has been quite sufficiently rapid to justify Professor E. C. C. Baly, F.R.S., of Liverpool, in compiling a third edition of his "*Spectroscopy*," the first edition of which came out in 1905, and to divide the book, originally of one volume, into two volumes. The first volume [Longmans, Green and Co.; price 14*s.* net] of this third edition, is now before us. Professor Baly is well known for his spectroscopic work, especially in the ultra-violet and infra-red, as well as for his experimental skill and ingenuity in adapting his instruments to his particular purposes. Every spectroscopist has to do that more or less, and physicists will be grateful that he writes chiefly for the man engaged in research work. Such work involves an intimate knowledge of the construction of slits, prisms and lenses, and of gratings and of the manner to use them; these matters, together with historical notes and the extreme region of the spectrum, are discussed in the chief sections of the volume of 298 pages which is illustrated by 138 text figures and provided with good subject and name indexes. The first volume, dealing with methods of working, should prove a good preparation for the theoretical deductions to be given in the second volume.

Being impressed with the fact that the literature on concrete and ferro-concrete is scattered through a variety of publications, which the engineer is hardly in the habit of consulting regularly, and that it will therefore be difficult for the engineer to find out what he might do when his concrete shows signs of corrosion or weakness, Dr. Ing. A. Kleinlogel, professor at the Technical High School of Darmstadt, has arranged his volume on "*Einflüsse auf Beton*" [Matters influencing Concrete; Berlin: Wilhelm Ernst and Sohn; price 18·90 Swiss francs] in the form of a dictionary. Considering further that secrecy still enjoys favour in the concrete industry, and that every engineer should keep his concrete under observation and record his observations, the volume is printed like a diary; the even pages and occasional further spaces are left blank for notes. After a general chapter on cements and binding agents, the volume discusses briefly the chemical, mechanical and other influences of acids, lyes, oils, steam, water, the soil, stored goods, &c., upon mortar and cements, including slag cements and concrete, and the precautions and remedies applicable to prevent and to cure corrosion. The arrangement is alphabetical; the first term discussed, at considerable length, is "Abdichten des Betonsgegen Wasser" (making concrete watertight). A little more might perhaps have been said concerning the action of calcium sulphate on cement and on the recent foreign literature—difficult to obtain in Germany now, of course. Dr. Kleinlogel hopes that his readers will enable him to supplement his volume which is entirely written from the technical standpoint.

Even as some other of the war-time movements have been gradually relegated to their correct places in industry, so has that much-lauded and equally condemned extravaganza known to harassed industrialists during the war period as "welfare" been placed in a more or less true perspective. Let loose by a Government in its distress at being unable to control and in its desire to placate the workers, whom its weakness had spoiled, large numbers of people—many of them faddists—fastened upon a useful work which, without the blare of trumpets, had been carried on by some of the more enlightened firms for years before the war; these people, because of their lack of knowledge of industry, men and manufacture, brought a most useful movement into such disrepute that its very name became anathema to large numbers of men and women responsible for the management of industrial concerns. The movement has been saved from its "friends," however, and it is quite refreshing to read a book on the subject in which the relative importance of production and welfare is recognised. Mr. John Lee in "*The Principles of Industrial Welfare*" (London: Sir Isaac Pitman and Sons, Limited, (Price 5*s.* net) puts the question in quite a satisfactory manner. He appreciates that "it may be that the flood of emotion . . . so directed men's thoughts that the wisest schemes were not adopted and that welfare work became a sort of fad inspired by kindliness rather than a seriously thought-out consideration of the principles of employment." He recognises also that "no longer is the employer a free agent under whatever conditions he chooses provided that a certain legal minimum is observed. He is faced with corporate bargaining . . . with vast organisations of labour. . . . with public opinion which has steadily become clearer as to the content of "Good Employment." All this is true and to some extent goes to indicate two facts: (1) that the welfare people have ridden their hobby-horse unwisely; (2) that adult labour—usually organised labour—is not dependent upon outsiders for its well-being, whatever name such outsiders may choose to take. This is not to say we think there is no place for well thought-out work which has for its object the true well-being of industry. We think, rather, such work is over due. Industry has been developed on lines in which, in great measure, the human factor has been ignored, and any movement which will help to humanise industry without impairing its efficiency is to be welcomed. At the same time this is not likely to be secured by grandmotherliness. Labour "does not ask for . . . molly-coddling, but it does ask for humaneness." While Mr. Lee goes far to put "welfare" in a sane light we do not agree with some of his contentions; in some respects, we think he assumes too much. Thus, excellence of workmanship is due to the presence of a standard rather than to the good-will of the workers. Good-will is desirable, but a standard of workmanship is essential if production of a specified class is to be obtained; a poor quality of work does not necessarily or at all indicate an absence of good-will. Again, "sanitation and ventilation" must be provided by the employer, independently of the worker's appreciation; there is no option, nor should there be. In another direction we could have wished more attention had been given to welfare work where junior labour and man-managed women are concerned. In both cases, but particularly the former, there is a real call for intelligent welfare work, although, to justify the term intelligent, a broader outlook is required than the arrangement of sports, games and whist drives, good though these can be. In this respect, welfare should have an educational outlook, should be character-building, good citizens being the aim, with the sure knowledge that good citizens are more certain to make good workers than are good workers to make good citizens. Taken in its entirety, however, Mr. Lee's book is an acceptable contribution on a subject which justifies more attention. It should help to bring about that good-will in industry which is so desirable, and it can well be used by many "welfare" people as a basis on which to recommence the work to which they have been such obstructionists.

Researches into the structure of the cosmos and of the movements and behaviour of the distant stars reveal systems that grow in complexity in proportion to the vigour with which enquiry is pushed. Able interpreters are needed, and it should be a matter of great satisfaction that those who have spent their vigour in such inquiries, and have struggled most successfully to overcome the many difficulties encountered in the pursuit, are willing to employ their enforced leisure in explaining to the public the results of their industry, with the view of making the world better informed concerning the mysteries of the heavens, to whose interpretation they have devoted their lives. This is the task that Professor G. E. Hale, Honorary Director of the Mount Wilson Observatory, has undertaken. In a little work, "*The Depths of the Universe*" (Chas. Scribner's Sons, New York; price 7*s.* 6*d.* net), he enables us to see some little of what has been accomplished in this magnificent observatory, reared by his genius and supported by the munificence of the Carnegie Institute. Only three main enquiries are referred to, namely, the methods of plumbing distant space, the presence of the dark material in the universe that may conceal as much of the grandeur of the heavens as it permits to appear, and the wonderful mechanism of the sun-spots—but these three topics should arrest the attention of all to whom the beauty of the heavens appeals. Taken in connection with a similar work, by the same cunning hand, "*The New Heavens*," one can enter into the labours of many astronomical experts, undecided whether to admire more the results of their energy or the skill and courage with which they contrived their experiments and carried them to a successful issue.

In September, 1922, a number of distinguished workers in the domains of hydrodynamics and aerodynamics met, on the instigation of Professors Th. von Kármán, of Aachen, and T. Levi-Civita, of Rome, in informal conference at Innsbruck. Lectures, none of great length, were delivered and discussed. These lectures, supplemented by a few further contributions and by abstracts of the discussion, have been edited in German translations by the gentlemen mentioned, under the title, "*Vorträge aus dem Gebiet der Hydro- und Aero Iynamik*" (*Innsbruck*, 1922) [Berlin: Julius Springer; price 3·10 dols). The names of the editors characterise the contents and are a guarantee for their value. Professor K rmán is amongst the foremost authorities on hydrodynamics, and Professor Levi-Civita is one of the mathematicians whose developments of Riemann's mathematics were of great help to Einstein in his principles of relativity. Among the contributors of papers are Prandtl, Treffitz, V. Bjerknes, L. Hopf, V. W. Ekman (sea currents) J. Thysse (tidal friction), J. M. Burgers (turbulence), R. Caldonazzo (rotation in liquids), R. Verduzio (starting of seaplanes), A. G. V. Baumhauer (helicopters) and D. Thoma (water turbines). Most of the papers concern aerodynamical problems. English scientists were not present at the conference.

Even in this country it is not every would-be student of mathematics that is able to attend lectures on the subject. Many reside in small towns or country villages, at which technical classes are non-existent and private coaching unattainable. In America matters are probably still worse, since distances rule greater. This condition of affairs has led on the one hand to the establishment of correspondence courses, and on the other to the production of text-books specially prepared to meet the needs of the private student. It is for this class of student that Professor C. I. Palmer has written his "*Calculus for Home Study.*" The work in question is arranged on original lines, and very great pains have been taken to achieve clearness and to avoid ambiguities. The author introduces the leading concept of the differential calculus by considering as a problem, of some interest to the curious, the rate at which one end of a ladder will move down a vertical wall, when its foot is dragged along the ground at a uniform velocity. This excellent example provides a very satisfactory illustration of a rate of variation which increases progressively but not uniformly the further the top of the ladder travels. The author makes considerable use of differentials, which for the mechanically minded afford undoubtedly the best basis for the study of the calculus. On the other hand the connection between integration and summation and the representation of an integral as the area of a curve are not introduced until late in the volume, although historically this method of regarding the integral calculus ante-dated that of considering it as the inverse of differentiation, which is the view point used by the author, in introducing the subject. The author, moreover, relegates co-ordinate geometry to the last chapter of the book. In both cases we have here a departure from the more general practice, but Professor Palmer claims to have had special experience in the teaching of mathematics to men who are unable to go to college. The private student, quite commonly, tries to get on too fast, and the author gives a salutary warning against such an ambition, and instructs his readers to return repeatedly to parts already read. Thus only can the average man acquire real familiarity with the principles of the calculus, which are based on ideas with which the ordinary school mathematics has little direct concern. A useful table of integrals forms an appendix to the volume. The treatise is issued by the McGraw-Hill Publishing Company, Limited, London, at 15*s.* net. A special word of praise is due to the excellence of the printing, paper and binding, and indeed of the whole get up of the little volume.

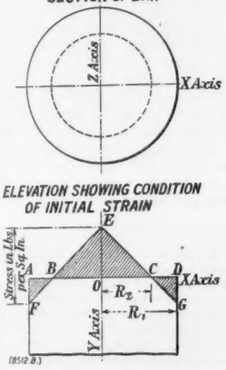
THE CALCULATION OF QUENCHING STRESSES IN STEEL BY USING DIRECT MEASUREMENTS.*

By T. McLEAN JASPER, Assistant Professor of Engineering Materials and Engineer of Tests, Fatigue of Metals Investigation, University of Illinois.

THE determination of the values of initial stresses set up in ferrous metals due to quenching is a problem which is of importance in the testing of such materials. The importance of these initial stresses and the extent of their effect on the static and fatigue properties of ferrous metals make them well worthy of a series of experiments. A description of a method of determining quantitatively the internal stresses set up by quenching, and the distribution of these stresses in the cross-section of a series of heat-treated bars, together with a discussion of their relative importance, are here undertaken.

Initial Strains.—When a bar of steel is heated to the neighbourhood of the critical temperature and suddenly quenched in water or oil, the outside fibres cool more rapidly than those inside, and, in consequence, they may reach a state of set before the inside of the bar has cooled off to the same temperature; with the result that, as the inside of the bar cools, its contraction is not allowed to take place freely to the normal-unstrained condition, and this part of the bar is held in a condition of initial strain. If, on the other hand, a bar of steel after being heated is allowed to cool very slowly, so that the cooling of each fibre takes place at about the same rate, the tendency for initial strains to be set up is so much lessened that the effect may be neglected. From the nature of the cooling effects it may be surmised that the outside fibres of a quenched material will be in compression, since the volume of the piece continues to decrease due to cooling after the outside layers have set; and, therefore, in order that a state of stress equilibrium may exist, the inside fibres must be in tension. This supposition is shown to be correct in the experiments which follow. It must be understood, however, that the first stage of initial strain on plunging in a cool liquid gives rise to tension on the outside fibres, tending to split the metal open. This is evidenced by the fact that metal sometimes splits if quenched carelessly or too rapidly.

Fig. 2.



If a quenched bar is tested in tension, it is conceivable that, as the stress is applied, the yield point will first be reached by that portion which is in initial tension; and in consequence, instead of the stress-strain curve changing abruptly as it approaches the yield point, it will begin to deviate from a straight line much earlier, and the yield point will not be so sharply defined. If the distribution and the values of the stresses in the cross-section of the piece could be accurately established, the deviation of the stress-strain curve from a straight line before reaching the yield point could be used to determine the value of the maximum quenching stresses set up in the steel. If the actual value of the initial stresses is of great importance in the usable strength of a ferrous metal, then the necessity for knowing the values of the initial stresses becomes very much more important.

Experiments.—The experiments from which the results herein presented were obtained were devised with the purpose of finding out the initial state of the steel under three important different conditions of heat treatment and also when subjected to a large number of reversals of stress below the yield point subsequent to these heat treatments.

The four sets of tests were conducted as follows:—

(1) A number of steels were brought to the critical temperature, quenched in water, and then tested for initial strains.

(2) A number of steels were brought to the critical temperature, allowed to cool very slowly and then tested for initial strains.

(3) A number of steels were brought to the critical temperature, quenched, reheated to various different temperatures, allowed to cool very slowly, and then tested for initial strains.

(4) Several of the steels heat treated as in (1), (2) and (3), were given additional treatment by subjecting them to a large number of reversals of stress in the fatigue-testing machine below the yield point of the materials and then testing for initial strains.

It was assumed that within the range of the experiments the stresses were proportional to the strains, and in consequence, the strains are eventually interpreted in terms of stresses. This assumption seems logical, since in general the quenching stresses thus found have been well below the respective static yield points of the materials. The quenching stress, however, may in one or two instances have exceeded the yield point of the material, although the general evidence available on the materials here considered does not support this contention.

Method of Measuring Initial Strains.—The method adopted in general for measuring initial strains was similar to that outlined by Howard*, and, independently by Heyn†. This method consisted in measuring the length of a round bar of metal after the removal of successive concentric layers in a lathe, and in interpreting the change of length of the specimen in terms of stress by the use of the elastic constants. In addition to this, in the present series of experiments, borings were made through the centre of a companion bar, and measurements of the length taken after successive cores had been removed. These operations were so conducted that the area of steel remaining in the solid cylinder could be used in comparison with the area drilled out of the companion bar in order to calculate the actual stress distribution curve.

Fig. 1.

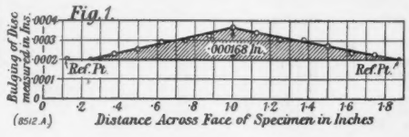


Fig. 3a.

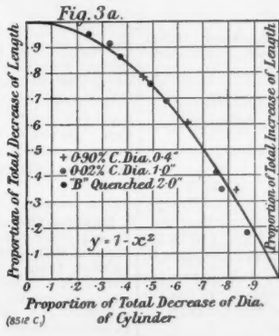
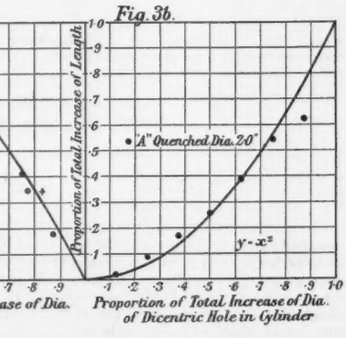

Proportion of Total Decrease of Length
+ 0·90% C. Dia. 0·4"
• 0·02% C. Dia. 1·0"
• "B" Quenched 2·0"
$y = 1 - x^2$
(8512 C.)
Proportion of Total Decrease of Dia. of Cylinder

Fig. 3b.


Proportion of Total Increase of Length
• "A" Quenched Dia. 2·0"
$y = x^2$
Proportion of Total Increase of Dia. of Dicentric Hole in Cylinder

Prior to these machining operations, the end portion was removed so as to avoid the complication set up by the end effects of quenching, and also to obtain a check on the distribution of the stress through the cross-section. The end surface of the specimen was then polished as nearly as possible to a plane surface, and a traverse made by using a micrometer sensitive to measurements of one three-hundredth-thousandth of an inch. A thin slab including the traversed end was then cut off and a retraverse made of the polished surface. A base line determined by two points on the surface was used as a reference line for all measurements. The changes of the surface elevations were then calculated and a curve indicating the distribution of stress relief was drawn up as shown in Fig. 1.

It will be noticed that the curve in Fig. 1 shows the highest point at the centre with two fairly straight lines joining the reference points chosen. The total elevation of the centre point above the base line is less than one five-thousandth of an inch. This diagram serves as an indicator of the probable shape of the distribution curve.

If the curve of stress distribution, therefore, is assumed to be nearly a straight line between the centre of the bar and the outer portions, and if the conditions of equilibrium are represented by the equations:

$$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$$

it is a simple matter to find the relative values of the ordinates in compression and tension.

Due to the fact that tangential and radial strains may be set up in the specimen on quenching, if a rigid analysis is to be considered, it must be seen from Poisson's ratio that the total value of the longitudinal strain may not represent directly the value of the maximum stress unless it is found that the average effect on that portion of the cylinder which is in longitudinal tension is balanced by its effect on that portion which is in longitudinal compression. If the radial tension at any point in a quenched cylinder is equal to the tangential compression at the same point there are sufficient grounds for assuming that the effects are balanced, and this assumption was made in the present case.

For the solution of the problem in question, therefore, measurements were made along the Y-axis only. The calculated value of the stress in tension was found to be one-half that of the stress in compression (see Fig. 2). Fig. 2 was drawn with the aid of Fig. 1, on the assumption that there is a straight line distribution of stress between the centre and outside portion of the bar.

If the distribution curve of Fig. 2 is applied to the case of the change of length of a quenched solid cylinder of steel as concentric layers of the material are removed, it can be shown that the decrease of length of the bar will vary with the change of diameter, according to the equation:

$$y = 1 - x^2,$$

where x is the proportional total decrement across the diameter of the bar, and y is the proportional total decrement along the gauge length of the bar.

In a similar manner, if concentric cores of the material are removed from the centre of the quenched cylinder, it can be shown that the increase of the inside diameter will vary with the increase of length according to the equation:

$$y = u^2,$$

where x is the proportion of the total increase of the diameter of the inside of the hollow cylinder, and y the proportion of the total increase in length of the cylinder.

The applications of these theoretical relations are shown in Figs. 3*a* and 3*b*; (*a*) shows the theoretical curve for the decrease in the length of a quenched steel cylinder as concentric layers are removed from the outside, and (*b*) the corresponding curve for the increase in length as the quenched cylinder is bored out. Experimental values obtained for three different sets of steel bars, varying in diameter from 0·5 inches to 2·0 inches and in carbon content from 0·02 per cent. to 0·90 per cent., have been plotted in Fig. 3 (*a*), and for one steel bar of 2 inches in diameter in Fig. 3 (*b*). The plotted results follow the theoretical curve very closely indeed in the case of Fig. 3 (*a*), but not so closely in the case of Fig. 3 (*b*). In obtaining these experimental results considerable care was taken to avoid increasing the temperature of the cylinders in the machining. This, however, could not be so successfully accomplished in the case of boring out the hollow cylinder, especially when the walls of the cylinder became thin.

The values obtained for the different quenched steels, where no further treatment was applied, are plotted in the curves in Fig. 3.

By reference to Fig. 2 it is readily seen that if the initial stress in tension as represented by the distance OE is present in a member to be tested statically in tension, the fibre OE will reach the yield-point load earlier than any other fibre, and in consequence the stress-strain diagram will begin to deviate from the straight line much earlier than would be the case if there were no initial stress present. From this consideration it would appear that it should be rather easy to determine the value of the maximum amount of initial stress from the difference between the static yield-point and elastic-limit values of a material. Assuming this to be true, and it seems logical that it it, it is obvious that the elastic limit is an accidental point rather than a fixed one, as is so often assumed. In the testing of metals in fatigue, this is brought out by the fact that the fatigue or endurance limit correlates not so much with the elastic limit as with the yield point or the ultimate strength of a material.*

The greatest effect of initial stress on the results of static testing will be found when the straight line relations, as shown in Fig. 2, hold; and the value of the maximum initial stress, if we assume that the initial stresses cause the stress-strain curve to deviate from a straight line before reaching the yield point,

* Paper read before Section G of the British Association at Toronto on August 12, 1924.

* Howard. "Test on Harveyised Bars," *Tests of Metals*, Watertown Arsenal, 1893, page 285.

† A. Martens and E. Heyn, "Materialienkunde für den Maschinenbau," 1912.

* H. F. Moore and T. M. Jasper, "An Investigation of the Fatigue of Metals," Series of 1922, University of Illinois, Eng. Exp. Sta., Bulletin No. 136, 1923.

will be two-thirds the value represented between the elastic limit and the yield point.

It has been noticed in the Fatigue of Metals Laboratory at the University of Illinois that, in a heat-treatment series where a very strong steel is used, the elastic limit of a quenched steel with no subsequent draw (tempering) is lower than one with a draw (tempering) of 600 deg. F. (see Figs. 4 and 5). In order to discover the reason for this a series of measurements for initial stress was made, and the results are shown in Table I. It will be seen that above 600 deg. F. Fig. 6 shows graphically the results obtained with a 0·50 carbon steel quenched after being raised above the lower critical temperatures. The upper curve shows the results before, and the lower curve the results after, the specimen has been run in a rotating-beam fatigue-testing machine.

A few specimens of different steels were tested for initial stresses after heat treatments approximating annealing, and the results are shown in Table III.

From Table III it is evident that the maximum initial stresses in annealed steels are very small indeed

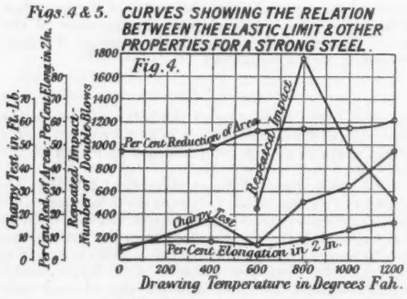
TABLE I.—THE EFFECT OF DRAWING (TEMPERING) ON THE MAXIMUM INITIAL STRESS FOR A 0·50 CARBON STEEL HEATED TO 1,500 DEG. F., QUENCHED AND DRAWN WITH NO APPLICATION OF REPEATED STRESS.

Draw Deg. F.	Strain Relief. in. per in.	Stress Relief in Centre Fibre. lb. per sq. in.	Diameter.		Per cent. Reduction of Diameter.	Maximum Value of Initial Stress.
			Orig. in.	Final in.		
						lb.
0	0·001157	34,300	0·950	0·650	68·5	49,700
300	0·001107	33,100	0·951	0·658	69·1	47,900
600	0·000760	19,300	0·950	0·650	68·5	28,200
900	0·000227	700	0·950	0·650	68·5	1,020
1,200	0·000100	350	0·950	0·651	68·4	505

TABLE II.—THE EFFECT OF REVERSAL OF STRESS ON THE MAXIMUM INITIAL STRESS FOR A 0·50 CARBON STEEL HEATED TO 1,500 DEG. F., QUENCHED, AND DRAWN. DIAMETER 0·40 IN.

Draw Deg. F.	Strain Relief. in. per in.	Stress Relief in Centre Fibre. lb. per sq. in.	Diameter.		Per cent. Reduction of Diameter.	Maximum Value of Initial Stress. lb. per sq. in.
			Orig. in.	Final in.		
0	− 0·00064	− 1,930	0·399	0·156	39·1	− 4,950
400	− 0·00099	− 2,970	0·398	0·158	40·6	− 7,000
600	− 0·00055	− 1,650	0·400	0·157	39·3	− 4,200
800	+ 0·00086	+ 2,570	0·400	0·164	41·0	+ 6,270
1,000	+ 0·00045	+ 1,350	0·400	0·154	38·5	+ 3,510
1,200	+ 0·00013	+ 385	0·400	0·157	39·3	+ 980
1,425	+ 0·00008	+ 240	0·400	0·155	38·8	+ 620

Figs. 4 & 5. CURVES SHOWING THE RELATION BETWEEN THE ELASTIC LIMIT & OTHER PROPERTIES FOR A STRONG STEEL.



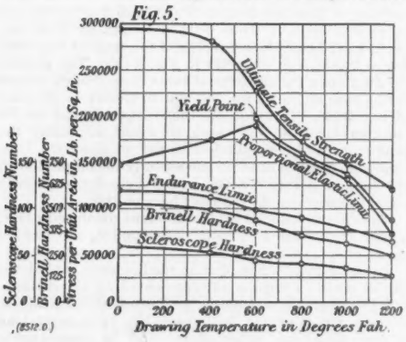


TABLE III.—*The Values of the Maximum Initial Stresses set up in a Steel given Approximately an Annealing Heat Treatment.*

Steel.	Treatment.	Maximum Initial Stress. lb. per sq. in.
0·90 carbon	Normalised ..	4,730
0·92 „	Annealed	2,260
0·49 „	1,200 deg. F. draw	505

in comparison with those occurring in quenched steels that have been given no subsequent heat treatment.

Summary.—The results recorded in this paper are from experiments on 35 bars of steel varying in carbon content and heat treatment; about 150 readings of gauge length were made on each bar.

The results indicate that the initial stresses set up in steel due to quenching are considerable. In the case of a few experiments not described here, on a nickel alloy steel, it was found that the quenching

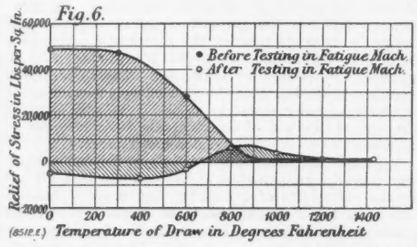


Fig. 6.
Before Testing in Fatigue Mach.
After Testing in Fatigue Mach.
Relief of Stress in Lbs. per Sq. In.
Temperature of Draw in Degrees Fahrenheit

draw the initial stresses are considerable, but that below this value of draw temperature they are practically negligible.

It has been noticed that the deflection of a rotating bar in fatigue seems to increase immediately after the beginning of the test, but from then on practically does not change for the remainder of the run; and also that the specimens exhibit a state of fever or a rise of temperature on being placed in a fatigue testing machine, this fever subsequently subsiding. This is especially true of heat-treated steel with very little draw after quenching. It was considered possible that the deflection change might coincide with the relief of strain due to working. Table II shows the effect of repeated stress on heat-treated steel.

In comparing Table I and Table II it is readily seen that the effect of repeated stress on heat-treated steel with high initial quenching stresses is to relieve those initial stresses to the extent of approximately 90 per cent. It is also demonstrated that the centre fibres have in some instances had the stress changed from tension to compression. In order that equilibrium may exist the outside fibres are changed from initial compression to initial tension through fatigue testing. stresses exceeded the ultimate strength of the material. This was indicated by the fact that several specimens cracked to the depth of over ¼ in. in quenching in water.

It would appear that fatigue testing has the effect of relieving initial stresses. This was previously suspected from the fact that in a regular fatigue test many specimens, after a few cycles of stress, exhibited a state of fever, or a rise of temperature, which subsequently subsided. This occurred in specimens which were tested to 100,000,000 cycles at the endurance limit without failure.

It is suggested that the difference between the values of the elastic limit and yield-point strengths of a steel might be used as an indicator of the maximum value of the initial stress by multiplying the value of this difference by two-thirds. This presumes a test with a sensitive extensometer.

It is also suggested that it cannot be presumed that the best heat treatment of a steel is shown by a small difference between the elastic limit and yield-point strengths, because subsequent fatigue tests of the materials do not show this to be an indicator.

It would appear, also, that the elastic limit or limit of proportionality between stresses and strains of a ferrous metal is largely dependent on initial quenching and subsequent treatment. From this it would appear that the elastic limit is not a static property which should be used as a basis in design. It is suggested that the yield point, and failing this the ultimate strength, is the best characteristic static property to use with a factor of safety consistent with the requirements of design.

THE COMPLETION OF THE SURVEY OF NORTH-WEST GREENLAND.

IT is announced by the Northern News Service that through the strenuous efforts of Dr. Lauge Koch, the well known Danish explorer, the last remaining unsurveyed portion of the Greenland coast, running north-west from De Long Fiord up to Cape Bridgeman, has now been mapped. Dr. Koch, who spent a previous eight years in exploration and scientific work in Greenland, was appointed leader of the Jubilee Expedition, recently returned. The work of mapping the coast involved the undertaking of the longest sleigh journey on record, a trip full of risk and danger, across glaciers and over a dreaded ice-cap of 3,600 miles, occupying 200 days.

The expedition, which started from Inglefield Gulf, near Cape York, consisted of 19 sledges, 200 dogs, and a few selected Eskimos; Dr. Koch was the only European of the party. Most of the time the temperature was — 40 deg. C., and great hardships were suffered both by men and dogs. On May 13, 1921, Dr. Koch finished his surveying work, and planted the Danish flag in latitude 83 deg. 50 min. North. The return journey was very hazardous, a detour having to be made via Warming Land. Food ran short, disease broke out among the Eskimos, and 190 of the dogs died or were eaten. In October, however, the expedition reached the base, having completed its work, the mapping of the territory between Independence Fiord and Humboldt Bay being accomplished on 10 sheets, drawn to a scale of 1 to 200,000, while the whole northern area from Upernavik around Denmark Fiord was also covered. Dr. Lauge Koch attaches great significance to the geological results of his expedition. He has secured some 4,000 geological specimens, including fossils of animal life from the earliest period, and of both European and American forms.

DEHYDRATION OF ALCOHOL BY MEANS OF GLYCERIN.—Since glycerin is known to take up water from liquids and vapours with which it is mixed and to retain the water on distillation, it occurred to Drs. E. Knecht and E. F. Muller, of the Manchester College of Technology, to try whether commercial alcohol could be dehydrated and converted into absolute alcohol by these means. The experiments were successful, and the method seems to be practical and not too expensive. There are two chief sources of trouble to be guarded against. The glycerin may retain some alcohol (as well as the water), and traces of glycerin may pass over with the vapours and contaminate the alcohol, although the boiling-point of pure glycerol is 290 deg. C. By distilling the alcohol-glycerin mixture twice, or by modifying the original process, Knecht found that both these objections could be met. The research was made last summer, and a paper on it was announced to be read before the Society of Chemical Industry last October; there was some delay however, and the paper was only published in the *Journal* of the Society of June 6 of this year, while Mariller had described a similar process in the October issue of *Chimie et Industrie*. Mariller works with alcohol vapours, whilst Knecht generally mixes the liquids, 25 per cent. by weight of glycerin being added to an alcohol containing 10 per cent. of water; stronger alcohol requires less glycerin for the treatment.

RAILWAY ENGINEERS' CONVENTION, BERLIN.—A Railway Engineers' Convention has been arranged by the Association of German Engineers, in conjunction with the German State Railways, to take place in Berlin from September 22 to 27. A number of papers are to be read and discussed, dealing with the organisation and economics of heavy transport; developments in the construction of permanent way and bridges; safety devices; signalling; the strengthening of existing railway bridges; connection for transfer of freight between narrow-gauge or road railways and main lines; improvement in the thermal efficiency of locomotives; steam condensing on locomotives; ball, roller, and ordinary bearings; the firing of locomotives with powdered coal; Diesel locomotives; the standardisation of locomotives and wagons; iron fire-boxes; the various locomotive component parts; brake and other tests; electric railways, &c. We learn from Messrs. Leistikow, Allison and Lyon, 19, Southampton Buildings, Chancery Lane, W.C.2, that Messrs. Borsig are very anxious to arrange for British engineers who may be attending the convention to visit their works at Tegel. Engineers who wish to avail themselves of this opportunity should communicate with Messrs. Borsig direct or with the London firm, stating the length of their stay in Berlin and the name of their hotel. Messrs. Borsig say that at Seddin railway station, near Berlin, there will be a large display of the most modern types of German State Railway and other locomotives, rolling-stock, &c., and other railway material.

WALLSEND-HOWDEN OIL-FUEL BURNING APPARATUS; EMPIRE EXHIBITION.

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

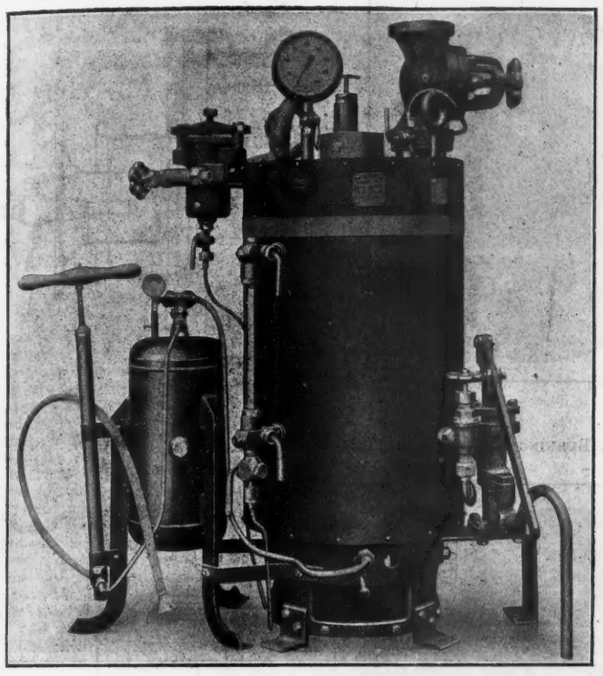
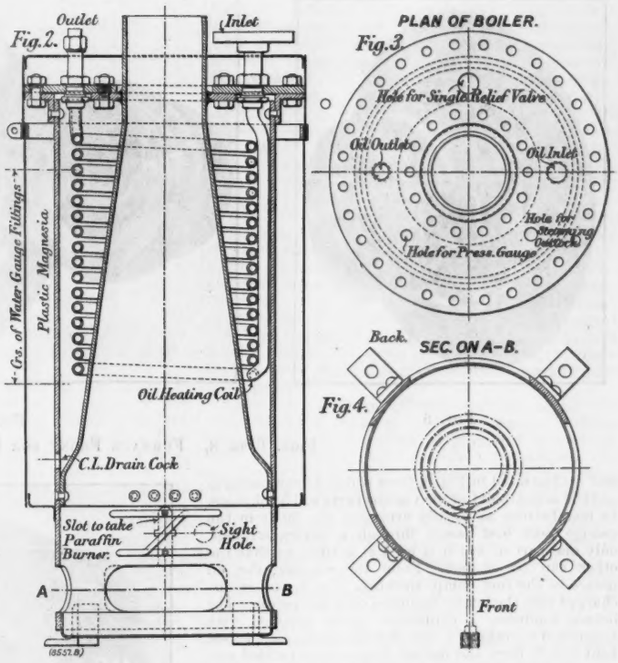


FIG. 1.



FIGS. 1 TO 4. STEAM RAISING APPARATUS FOR OIL FUEL INSTALLATIONS.

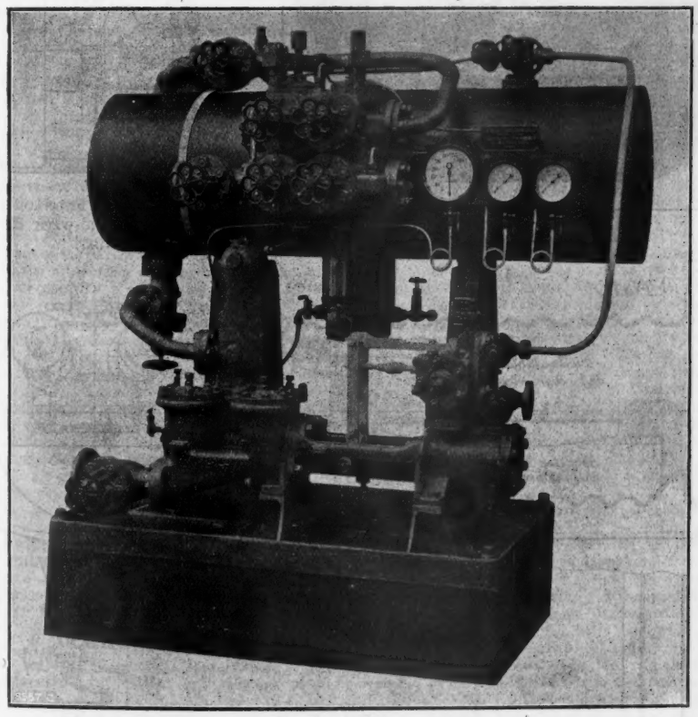


FIG. 5. COMBINED PUMPING AND HEATING UNIT.

WALLSEND-HOWDEN OIL-BURNING APPARATUS.

THE remarkable developments in the application of oil fuel to industrial heating processes and to steam raising, particularly in marine boilers, have frequently been referred to in our columns, and engineers are now generally familiar with the progress made. Oil, as is well known, has almost entirely superseded coal for firing the boilers of naval vessels, and, in the case of merchant ships, some 29 per cent. of the world's steam tonnage is now employing oil as fuel. On land, it is hardly possible to estimate the extent to which coal has been displaced by oil, but, even in this country, where coal must be regarded as the natural fuel, oil is being employed for boiler firing and heating operations in numerous land installations where its cleanliness, labour-saving characteristics, and ease of control are important considerations. The advantages of oil fuel in these respects may now be regarded as well established, and interest in the subject of oil-fuel burning mainly centres round the design and arrangement of apparatus for the purpose of improving efficiency, reliability and safety in use. As is well known, the Wallsend Slipway and Engineering Company, Limited, Wallsend-on-Tyne, have had a long and wide experience in the application of oil-fuel firing, on the Wallsend-Howden system, to marine boilers, as well as to land installations, so that some particulars of the firm's latest practice, as exemplified in their exhibit at the British Empire Exhibition, should prove both interesting and useful to engineers.

We may first refer to the special apparatus provided for use while raising steam in the boilers, when no steam is available for working the pumps, heating the oil, or for atomising the oil if the steam-jet system is employed. The apparatus is illustrated in Figs. 1 to 4 on this page, and, as will be seen, comprises a small auxiliary boiler containing an internal coil, shown in Fig. 2, through which the oil is passed and heated to a temperature at which it is readily inflammable. The boiler is usually worked at a pressure of about 100 lb. per sq. in. When the pressure system of atomising is employed, the steam pressure in the auxiliary boiler is kept just below that at which the safety valve lifts, so that there is no loss of steam and no feeding of the boiler is necessary, although a small hand-operated feed pump is provided as shown in Fig. 1. The auxiliary boiler is fired by a paraffin burner, which can be closely adjusted to suit the requirements of each particular installation. The paraffin for the burner is stored in the cylindrical container shown on the left of Fig. 1, the necessary air pressure being supplied by the hand pump also visible in the illustration. The same pump, it may be mentioned, is used for filling the container with paraffin, which is drawn from a bucket through a hose connected to the pump suction. The fuel oil to be heated for supplying the main burners is delivered to the heating coil in the boiler by means of a hand-operated or auxiliary power-driven pump, the oil entering through the stop valve seen at the top of Fig. 1 and passing out through the strainer on the left of the illustration. Provision is made for steaming out the heating coil with steam from the boiler, the cock and pipe connection for this purpose being visible in the illustration immediately to the left of the lifting eye-bolt.

The firm's latest design of pumping and heating

WALLSEND-HOWDEN OIL-FUEL BURNING APPARATUS; EMPIRE EXHIBITION.

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

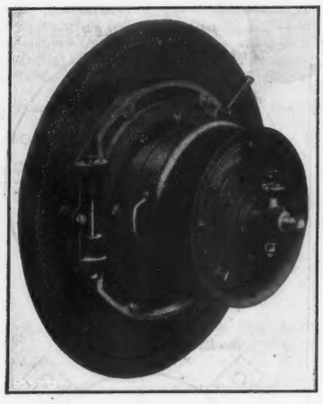


FIG. 6.

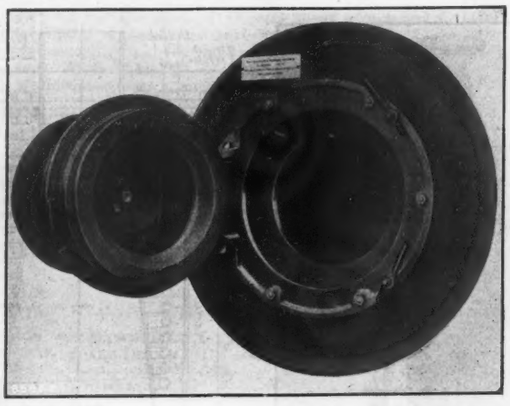
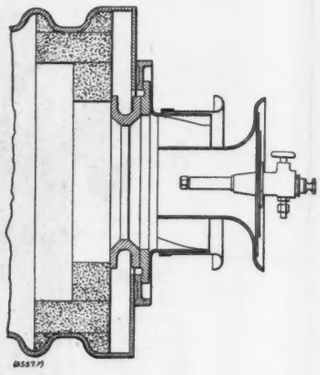


FIG. 7.



FIGS. 6 TO 8. FURNACE FRONT FOR OIL BURNING WITH NATURAL DRAUGHT.

unit is illustrated in Fig. 5, from which its compactness and the accessibility of the various parts will be obvious. In installations as usually arranged, the oil from the storage tank first passes through a duplex strainer, only one part of which is used at a time, so that the other can be cleaned. From the strainer, the oil passes to the fuel pump, shown in Fig. 5, and is discharged into the heater mounted over the pump. The heater comprises a cylindrical vessel supplied with steam and containing a nest of solid-drawn steel tubes, bent into U form and having their ends expanded into a single tube plate, which is also of steel. The tubes are thus free to move under the influence of temperature variations without any risk of becoming loose. A steam connection, shown on the right of the illustration, is provided to enable the tubes to be blown through, and special flexible cleaners are supplied, which can be passed through the tubes to remove any solid deposit. The heated oil passes out through the duplex discharge strainer mounted in front of the heater, as shown in Fig. 5, and thence flows to the burners. Two complete pumping and heating units of the type illustrated are generally provided for each installation, one unit being of sufficient capacity for dealing with the whole of the oil required at full load and the other acting as a standby.

Several different furnace arrangements are employed with the Wallsend-Howden system of oil burning, the particular arrangement adopted depending upon the form of draught employed and upon whether oil is used exclusively or alternatively with coal. Figs. 6, 7 and 8, above, illustrate the arrangement of the furnace front for a marine boiler burning oil only, in conjunction with natural draught. From the part longitudinal section, reproduced in Fig. 8, it will be understood that the bridges, bearers and firebars used when burning coal have been omitted, and a special front fitted which accommodates the burner and air director. With this arrangement, there is a considerable gain in combustion space and effective heating surface, and better circulation is promoted in the boiler owing to the fact that the lower part of the furnace is heated equally with the upper portion. Consequently, increased evaporation and high efficiency are obtained. The hinged air directors, clearly shown in Figs. 6 and 7, permit easy access to the furnace for cleaning and inspection, and they consist of two concentric trunks with helical vanes fitted between them. The vanes, best shown in Fig. 7, impart a swirling motion to the air in the furnace, and also, of course, to the fine particles of oil carried along with the air, the effect being to retain the burning hydro-carbons near the front of the furnace, so that combustion is completed before the gases leave the intensely hot zone formed at this part of the furnace. This, it will be understood, is the best condition for efficient combustion and the prevention of smoke. The main air supply through the directors to the furnace is regulated by a sliding sleeve, shown in Figs. 6 and 8, and the position of the flame is adjusted by means of a rotating perforated plate in front of the director, most clearly visible in Fig. 6. By increasing the air supply through the holes in this plate, the flame is thrown farther back into the furnace and reducing the air supply through these holes brings the flame more to the front of the furnace. The correct position for the flame is, of course, dependent upon the quantity of oil being consumed and also upon its quality.

Figs. 9 and 10 illustrate a furnace front arranged

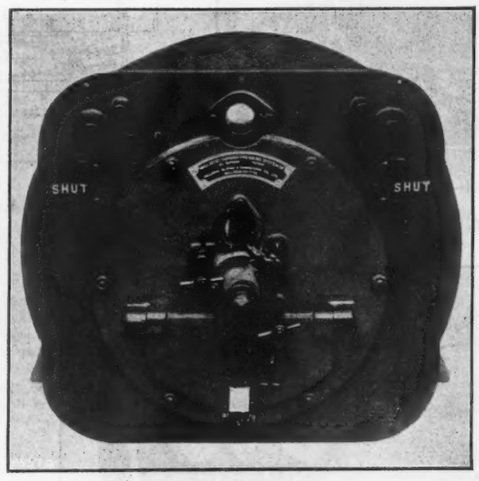
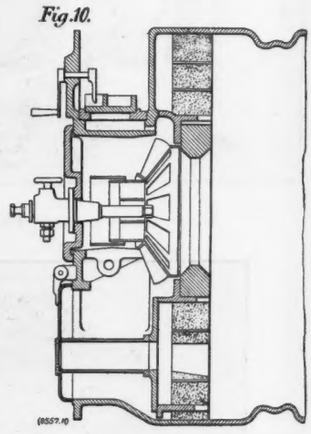


FIG. 9.



FIGS. 9 AND 10. FURNACE FRONT FOR OIL BURNING WITH HOWDEN FORCED DRAUGHT.

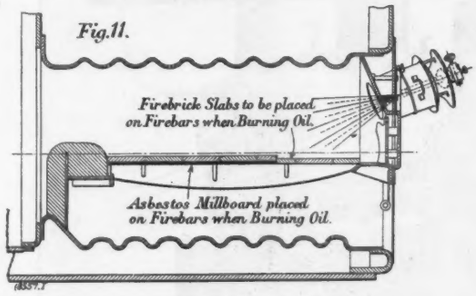
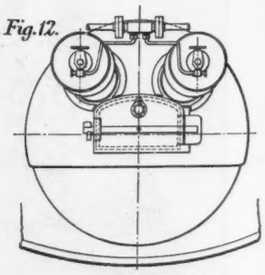
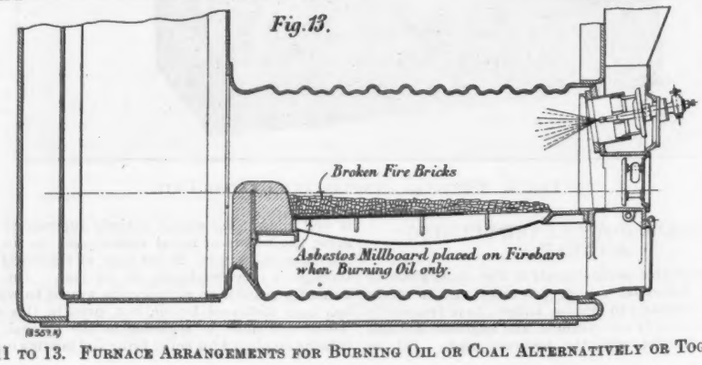


Fig.11.
Firebrick Slabs to be placed on Firebars when Burning Oil.
Asbestos Millboard placed on Firebars when Burning Oil.





FIGS. 11 TO 13. FURNACE ARRANGEMENTS FOR BURNING OIL OR COAL ALTERNATIVELY OR TOGETHER.

WALLSEND-HOWDEN OIL-FUEL BURNING APPARATUS.

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED.

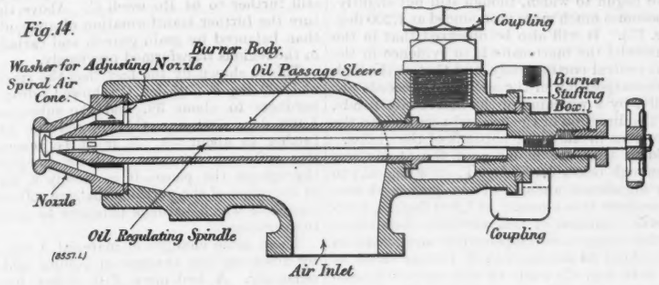


FIG. 14. LOW AIR-PRESSURE BURNER FOR METALLURGICAL FURNACES.

for burning oil with Howden's system of forced draught and having the bridge, bearers and firebars removed for the reasons explained above. The method of controlling the air supply will be obvious from the illustrations, but we may mention that this form of front can be readily removed in port if it is desired to revert to coal firing. If still greater facility for changing from one fuel to the other is desired, so that the operation can be carried out with the boilers under steam at sea, the furnace arrangements illustrated in Figs. 11 to 13 are employed, which also permit coal and oil to be burnt simultaneously. Figs. 11 and 12 show the arrangement used with natural draught and Fig. 13 that used with Howden draught. In both cases, the firebars are left in position, and, when burning oil, a sheet of asbestos millboard is placed on them and covered with firebrick slabs or pieces of broken firebrick. There is obviously no gain of combustion space or heating surface with these arrangements, so that they are only employed where rapid interchangeability of fuels is of greater importance than maximum efficiency. Wherever possible, the burner should be located in the longitudinal axis of the furnace and the firebars and other obstructions removed as in the arrangements illustrated in Figs. 6 to 10.

For land installations, the firm are exhibiting a complete Wallsend-Howden steam-jet installation for small boiler plants, which, however, is also employed at sea for firing the donkey boilers of motor ships. A small oil-fired hardening furnace is also exhibited, this furnace being fitted with the Wallsend low air-pressure burner, a sectional drawing of which is reproduced in Fig. 14 above. In this burner, the oil entering through the connection on the right passes along a central sleeve and escapes through the annular opening formed between the sleeve and a coaxial regulating spindle. The latter, it will be seen, is formed with a tapered portion so that by moving it longitudinally by means of the handwheel and screw shown in the illustration, the area of the annular opening, and consequently the quantity of oil passing, can be adjusted according to requirements. The regulating spindle terminates in what may be described as a button, which is situated in the nozzle outlet of the burner, and the oil issuing in a thin film from the annular opening is caught by the air blast and carried over the sharp edge of the button. By this means an exceedingly fine spray is produced, even with heavy and viscous oils, so that the burner can be used for metallurgical furnaces of all kinds as well as for heating ovens, galleys, &c. The burner is made in several sizes, and the air pressure necessary ranges from 10 in. to 25 in. water gauge, according to the size of the burner and the purpose for which it is required. It should, perhaps, be mentioned that the nozzle of the burner is provided with internal vanes to give the air a rotary motion and also that the longitudinal position of the nozzle can be adjusted by inserting a washer of the required thickness between it and the burner body.

The firm's exhibit includes a number of photographs of land and marine oil-burning installations they have supplied, as well as of marine steam engines, turbines, boilers, Diesel engines, &c., constructed at their Wallsend works for merchant vessels and warships of all descriptions.

ON THE NATURE OF HIGH-SPEED STEEL.*

By MARCUS A. GROSSMANN and EDGAR C. BAIN
(Dunkirk, N.Y., U.S.A.)

THIS paper is intended to give a more or less complete account of the physical phenomena occurring in high-speed steel from the time of casting the homogeneous melt to the production of the hardened tools, so far as the changes in the nature, amounts and distributions of the well-known constituents of such steel are concerned.

The Ingot.—The ingot of high-speed steel shows the characteristic structure found in all ingots of cast steel. There are columnar grains extending inward, with major axes normal to the ingot surface from which they grew. The central portion of the ingot contains more or less perfectly equi-axed grains.

Photomicrographs of high-speed steel ingots call to mind the microscopic appearance of white cast iron, and this similarity is sufficiently marked to afford a convenient analogy for use in study. The high-speed steel structure immediately after solidification is undoubtedly very similar to the structure found in a low-carbon hypo-eutectic white iron of about 2·0 per cent. carbon content. Primary grains of austenite, cored and more or less decomposed, plus eutectic (carbide-austenite) regions constitute the fundamental material of the ingot.

The columnar surface grains and the internal grains of the ingot are cored to an unusual degree. The crystallites solidified first differ very greatly from the subsequently filled-in portions of the primary grains. The magnitude of this disparity in composition of the original austenite grains from centre to periphery, and the persistence of the resulting cored structure, play a most important part in all the subsequent phenomena, and indeed are the cause of most of the manufacturing difficulties encountered. It is well to bear this point in mind constantly, and to recognise at all times that there is a gradation of concentration of carbide from the centres of the dendrites to the eutectic, and that this same gradation persists tenaciously in the finished bar of high-speed steel. It is believed that the diffusion of these carbides, once the steel is solidified, is very slow indeed, and that the ordinary heating and manufacturing operations help comparatively little in securing uniformity.

In the unannealed ingot the usual amount of eutectic found is about 13 per cent. This figure is, of course, slightly in excess of what is normal for the composition, because the metal solidified first is much poorer in carbide elements than the last to solidify, which is completely saturated with them. The last portion of the primary grains to solidify is, as always, richer in all alloying elements. The eutectic temperature is probably very close to 2,450 deg. F. (1,340 deg. C.). Within the eutectic regions the carbide is the continuous phase, and the austenite fills in the disconnected lakes. For completely homogeneous primary grains the eutectic regions probably would not exceed 10 per cent. of the whole.

The usual ingot of standard practice cools at a rate which not only does not preserve the primary grains wholly austenitic, but even permits of the nearly complete divorce of carbide in a spheroidal condition. In the grains near the surface the structure might be classed as sorbite, while in many of the internal grains the spheroidisation is coarse. Reference to photomicrographs will reveal the fact that while in the centre, or first solidified part of each grain, the carbide agglomeration has taken place to completion, the periphery, or last solidified portion of each grain, is still austenitic; no carbide has precipitated here. The boundary between these two structures marks the critical composition at which the particular rate of ingot cooling can effect the austenite-pearlite transformation. There can be no inference other than that saturated austenite in high-speed steel is very stable indeed. The stabilising action of alloying elements found in steel is probably in the order carbon, manganese, chromium, nickel, cobalt, molybdenum and tungsten. In high-speed steel chromium may have the major influence in stabilising the austenite. It will subsequently be seen that in finished steel there is never produced by any heat treatment austenite so rich in the carbide elements as this material in the ingot last to solidify, located near the carbide eutectic regions.

Within the primary grains of the ingot the boundary between the transformed and the untransformed austenite is usually marked by a nearly continuous band of carbide. Just outside this band there is usually present a zone of darkly etching material with a troostitic appearance, representing probably incipient transformation of the retained austenite. The location and appearance of this constituent suggest strongly the development of troostite at a fairly low temperature, whereas the interior of the grains transforms readily enough and at sufficiently high temperature to allow of complete spheroidisation of the carbide. Even this zone probably, to some extent, contributes to the carbide band. This may be caused by the high concentration of carbide elements in the outer region. If diffusion were not so very sluggish in high-speed steel there would have been a constant migration from these rich regions to the poorer for precipitation. The carbide band within the grain is doubtless the result of such action greatly restricted. It is the authors' opinion that slowness of migration of the alloying elements in high-speed steel is its fundamental property. It will subsequently be seen that in the finished tools there often remains a trace of this composition gradient from centre to edge of each grain.

That there is profound difference between the material of the interior of the grains and the material solidifying later, outside of the carbide dividing-line referred to, may be strikingly seen in the microsection. To accentuate this difference, specimens from the centre of the unannealed ingots were heated to 1,400 deg. F. (760 deg. C.), etched and photographed. The austenite rims of the grains were transformed to the very darkly etching troostite-sorbite material, while the interior region merely became more coarsely spheroidised.

The Annealed Ingot.—In manufacturing practice the ingot may be annealed before heating for forging, or it may be taken directly from the casting operation, while still hot, to be forged. In the case of annealing, the cooled ingot is heated up over a period of six to eight hours to a temperature in the neighbourhood of 1,600 deg. F. (850 deg. C.), held at this temperature a short time and then cooled slowly, consuming perhaps six to eight hours in cooling to 800 deg. F. (425 deg. C.). Before annealing, the ingot consisted of primary grains (composed of two structures) and eutectic regions. The two structures of the grains were austenite (near grain boundaries and near eutectic regions), and spheroidised pearlite or sorbite. The whole of the primary grains have changed to spheroidised pearlite and sorbite, and the eutectic patches have been very slightly dissolved. The carbide thus dissolved has been reprecipitated in the cooling time of the anneal, but the composition gradient from centre to last solidifying portion of the grains is still apparent. It should be noted that the ingot now consists of eutectic carbide regions of essentially the same size and formation as when cast, and grains of completely spheroidised pearlite or sorbite. These grains vary from point to point with the original concentration gradient, but there are actually many ferrite grains in which some elements are in true solid solution and within which tiny carbide particles are precipitated. There are two orders of carbide at this stage—the very fine globules and vastly larger lace-like structures of original eutectic. It is not unusual at this stage to find one of the eutectic areas of a section extending for a sixteenth of an inch, whereas the spheroidised carbide particles are usually not over 0·00004 inch in thickness, although they are sometimes longer in some dimensions, being at times cylindrical or slightly disc-like in contour.

In general, extremely rapid solidification produces very many fine grains in any metal casting, and slower cooling develops large-cored grains. The small grains are most easily homogenised, because although they, too, are cored, the distances for atomic migration involved in diffusion are short. When, however, extremely slow solidification takes place, a uniform composition is encouraged although the grains are large, because time is given for reaction between melt and solid. The portions of the crystallites freezing first are richer in iron and lower in carbide; given time, they will to a certain extent redissolve, being to that extent replaced in the crystal lattice by atoms in proportions more nearly representative of the melt.

Having in mind this property of solidifying melt, the authors believed that high-speed steel solidified over a long period of time would have a very nearly uniform composition throughout any single primary grain of austenite, and that in such material there would be a smaller amount of eutectic. Such a material was obtained which probably solidified at a rate of not more than ¼ inch in forty-five minutes. The subsequent cooling of this material (after freezing) was somewhat more rapid than would ordinarily occur even in very small ingots, corresponding in rate with an air cooling of rolled bars.

Photomicrographs by the authors show that while

* Abstract of a paper read before the Iron and Steel Institute, London, on Thursday, September 4, 1924.

the original austenite has extensively transformed to martensite in the interior part of every dendrite, martensitisation has stopped near the grain boundaries, and particularly near the patches of carbide. The inference is that the alloying elements were too concentrated to permit the transformation. This unique material was further utilised in several tests recounted below. Its interest lies in the circumstance of its having the highest possible concentration of dissolved carbide elements and the minimum amount of carbide eutectic. The martensite structure, present here so strikingly, will be discussed later in its relation to the usually found structure of hardened high-speed steel.

It is believed that it may be of interest at this point to deal with the gradual destruction of the intricate figures of the eutectic regions accompanying the cogging of the ingot. In general, the original grains of the ingot are deformed in much the same manner as is the whole ingot. The grains are also flattened; but the crumbling of the carbide eutectic is more significant, and shows clearly the origin of the "carbide streaks" in high-speed steel bars. If the large carbide particles in the high-speed ingot were solid integral masses the problem of producing a steel with uniform dissemination of small carbide particles would be difficult indeed, probably requiring high temperatures for solution and extreme severity of reduction. But the carbide regions are frail open structures, and friable as well, hence they disintegrate with comparative ease. In subsequent forging, the carbide eutectic rapidly breaks up so that the distribution of carbide becomes merely a matter of mechanical work to effect a thorough "kneading" of the mass.

It is perhaps well to point out that the whole of the good effect of prolonged working in rolls or under the hammer is traceable to the uniform distribution of small carbide particles throughout the material. In the utilisation of the steel, provision must have been made for the production of a homogeneous concentrated solid solution, in γ-iron, of as much carbide as possible. This can only be done by the complete crushing up of the original carbide eutectic regions and the obliteration of the original coring effect. The work actually is accomplished well in, for instance, small high-speed steel drill rod, so that the carbide particles derived from eutectic areas are nearly indistinguishable in size from the particles which have been divorced spheroidally from austenite solid solution.

It is not to be inferred that solution and reprecipitation are not responsible for some removal of the carbide streaks of the billets resulting from the eutectic areas. This effect is the more pronounced the smaller the size rolled from the ingot, but in all but the smallest size of steel bars the carbide distribution is largely a matter of mechanical "kneading."

As an example of the persistence of the coring effect of the primary grains a photomicrograph taken of a 1-in. twist drill which was actually an excellent tool, showed a typical carbide streak which was in reality an elongated and crumbled eutectic region. The matrix of sorbitic material about this carbide area was however, not uniform in composition. Some of the material near the carbide streak was scarcely etched at all, while at more remote points the material etched black. The greater concentration of carbide elements in the adjacent area had probably acted both to reduce the attack of etching acid and also to prevent the precipitation of carbide particles, which, being unresolved, photographed black. In a photograph of a longitudinal section of a large high-speed steel tool bit, the "streaky" nature of the structure is clearly in evidence, and in the portions etching lighter (the richer regions) the carbide particles remaining from the eutectic are larger than those in the darker region, which were precipitated from solid solution.

To summarise, then, high-speed steel requires generous reduction from the ingot, because, in the large sizes at least, the improvement by homogenisation is so largely accomplished by mechanical kneading and very slightly by diffusion. The cores are "churned" out gradually and the eutectic regions fragmentised. In small sizes, solution during annealing followed by reprecipitation contributes to uniformity of structure and refinement of carbide particles.

Martensite in High-Speed Steel.—The high-speed steel which had solidified with extreme slowness and had then been cooled rapidly, is here called material A. It shows large austenite grains with well-defined characteristic martensite markings. In order to determine the stability of this austenite-martensite mixture, and to study the manner of its decomposition, a sample was heated for half an hour at each of a series of comparatively low temperatures, corresponding with drawing temperatures for high-speed steels. The series of photomicrographs shows the significant manner in which this material responds with the low-temperature reheatings. The lower range of drawing temperatures, up to 900 deg. F. (about 500 deg. C.), has comparatively little effect, the martensite practically not changing at all. The hardness likewise remains about the same, as the original piece showed about 55 Rockwell C,* and the value after successive draws at 600 deg. and 900 deg. F. (315 deg. and 482 deg. C.) was still at about the same figure. When, however, the drawing temperature has been raised to 1,100 deg. F. (593 deg. C.), it will be observed that the original martensite needles have begun to widen, though still but slightly. The effect becomes much more pronounced at 1,200 deg. F. (648 deg. C.). It will also be observed that in the undrawn material the martensite is in evidence in the grains in the central portions only, and that at the high draws the decomposition of the austenite proceeds not only laterally, by a widening of the martensite bands, but also in the direction of the original needles into the austenitic regions in the outer portions of the grains.

It is evident that the mobility of the atoms was not great enough below 1,100 deg. F. (593 deg. C.) to permit any significant amount of the preserved austenite to transform into α-iron. At 1,100 deg. F., however, a decisive amount of this austenite does transform, and the change is accompanied by an increase in hardness to about 59 Rockwell C. A further draw at 1,200 deg. (648 deg. C.) leads to still further decomposition of the austenite, accompanied by further increase in hardness to 64 Rockwell C. The first very marked change in microstructure is observable here. The decomposition has now progressed sufficiently to establish the fact that the austenite is transforming along regions which are contiguous with the original martensite needles, and that the transformation progresses outward from them in all directions. The transforming process is a slow penetration from the original martensite needles into the austenite regions, the layers of austenite bounding the regions of α-iron giving way in slow progression as they too transform to α-iron. Heating further to 1,300 deg. (705 deg. C.) merely causes the decomposition to proceed further, and at 1,400 deg. F. (760 deg. C.) the breaking down is nearly complete. It is significant of the sluggishness of the reactions in high-speed steel, however, that even at a drawing temperature of 1,400 deg. (760 deg. C.) the austenite formed in material A was not wholly decomposed. The characteristic white patches in the microphotograph show the stable character of this austenitic material, which was still preserved after heating for half an hour at 1,400 deg. F. (760 deg. C.). It also gives a very clear and significant indication that high-speed steel probably never martensitises so completely as, for example, a piece of 0·60 per cent. carbon steel. The number of martensite needles in high-speed steel is limited, and the intervening regions are austenitic. Obviously, this is an instance where the fallacy of assuming that a specimen showing martensite needles is completely martensitic must be avoided.

It is believed that the phenomena observed in this material A are perfectly characteristic of the reactions taking place in the drawing of a piece of quenched high-speed steel. The authors believe that this specimen, far from being extraordinary, merely possesses to a more obvious and demonstrable degree the structures found always in high-speed steel. In newly quenched high-speed steel the austenite grains have numerous martensite markings, which can be observed after suitable etching but which are not so clear as in the present instance because the austenite grains are not so homogeneous, and are often small and thoroughly strewn with carbide particles. This lack of homogeneity in ordinary quenched high-speed steel is due to two factors: (1) the coring in the original dendrites has led to the presence of composition gradients which have not been wholly removed; (2) the accidental placing of eutectic carbide particles at numerous scattered points due to the working of the steel and the resultant kneading and churning action has caused small regions of local concentration gradients (due to solution) when the steel was heated to the quenching temperature. In material A, the austenite grains formed with good diffusion in solidification, so that they are quite homogeneous, and the eutectic carbide is of course segregated in grain boundaries. In other words, the crystallisation in the austenite lattice in material A has been much more symmetrical and uniform throughout large regions, so that the recrystallisation to α-iron (martensite needles) in the quench could take place without interruption along much longer paths and more completely.

The hardness changes which accompany this gradual breaking down of the austenite are of interest in connection with the secondary hardness phenomena in high-speed steel. Material A, when reheated to low temperatures, preserved its original hardness of 55 Rockwell C, unchanged up to a temperature of 900 deg. F. (482 deg. C.). At 1100 deg. (593 deg. C.) there was sufficient recrystallisation into fine-grained α-iron to raise the hardness to 59, and at 1,200 deg. F. (648 deg. C.) the proportions of austenite and transformed material were such as to increase the hardness still further to 64 Rockwell C. Above this temperature the further transformation of austenite was more than balanced by grain growth and carbide formation in the regions transformed previously.

This is shown by the fact that the specimen drawn at 1,300 deg. F. (705 deg. C.) showed a drop in Rockwell hardness to about 58, and the subsequent draw at 1,400 deg. (760 deg. C.) lowered the hardness still further to about 49. It must be remembered that this softening does not indicate complete softening throughout the piece—it is merely a preponderance of the effect of the portions that are softening over the austenite which hardens (changes to α-iron) at these temperatures.

These same changes in material A can be followed by observing the changes in volume which occur on reheating. A test-piece 2·0 inches long was prepared, and ground as nearly as possible with parallel ends, so as to make it possible to measure the length after various heat treatments. The length was measured on two instruments. One was equipped with an Ames dial reading to 0·001-inch with a 1 : 10 multiplying device, so that the instrument could be read directly to 0·0001 inch. The other was a Federal dial reading directly to 0·0001 inch. The readings taken were in each case the average from the figures of two operators on each of the two instruments. It was observed that there was no significant change in the length (*i.e.*, in the volume) until the steel had been reheated to 1,100 deg. F. (593 deg. C.). At this temperature a very considerable expansion set in, to be followed by further expansion at 1,200 deg. (648 deg. C.). Beyond this temperature the steel begins to contract, but here again it must be borne in mind that we observe merely a preponderance of effect. The contraction due to formation of carbides and to grain growth of the sub-microscopic grains of α-iron is more than sufficient to counterbalance the expansion due to transformation of further austenite.

(To be continued.)

* The dial used in the Rockwell hardness-tester "C" Scale records readings made by the impression of a 120 deg. diamond cone at a pressure of 150 kilogrammes. 70 C (the highest reading) corresponds with Brinell hardness No. 745, and 0 C with Brinell No. 140, but the intervening equivalents do not interpolate strictly. For further information as to the Rockwell tester, see paper by S. P. Rockwell, *Transactions of American Society for Steel Treating*, 1922, vol. ii, pp. 1013–1033.

ELECTRICITY SUPPLY FOR ADEN.

We understand from Mr. E. M. Duggan, A.M.Inst.C.E., the Chairman of the Aden Settlement, that arrangements have now been made for the supply of electricity in the Settlement and Cantonment of Aden and that the scheme is expected to be in operation by September of next year. A licence has been obtained by the Executive Committee of the Settlement, under the Indian Electricity Act, and the scheme prepared by the committee's consulting engineers and agents, Messrs. Barry, Wolfe Barry and Messent, 2, Queen Anne's-gate, Westminster, S.W.1, has been adopted and will be financed by a loan from the Government of Bombay.

The tender of Messrs. Crompton, Limited, of Chelmsford, for the power house, which has been accepted by the committee, calls for the installation of three Vickers-Spearing boilers and three 250 kw. turbo-alternators to be delivered at Aden in eight months' time, together with the necessary auxiliary machinery. Messrs. W. H. Allen and Sons, Limited, Bedford, will construct the turbines and Messrs. Crompton the alternators. Three-phase current, generated at 6,600 volts and 50 cycles, will be transformed down and supplied to consumers on the three-phase, four-wire system at a pressure of 230 volts per phase. The maximum charges allowed under the terms of the licence are 6 annas (about 6½*d.*) a unit for lighting, heating and fan driving, and 4 annas (about 4½*d.*) a unit for power purposes, with a minimum charge of Rs. 3–8 annas (about 5*s.*) a month to each consumer connected. An engineer will shortly be appointed to investigate the transmission and distribution system on the spot.

London University College Engineering Syllabus.—This publication for the session 1924-25 has come to hand and contains particulars of the requirements for the Engineering Degree and Certificate courses. Opportunities are to be provided for post-graduate study in a number of subjects and those interested may secure copies from the Secretary, University College, Gower-street, London, W.C.1.

The Sir John Cass Technical Institute.—The session 1924–25 of this Institute will commence on Thursday, September 18, when instruction will begin in pure and applied mathematics, physics, chemistry, fermentation industries, petroleum technology, metallurgy, arts and crafts, and languages and trade classes. Research facilities are provided as well as preparatory courses for the examinations of the University of London, the City and Guilds of London Institute, and of the Institutes of Physics, Chemistry and Brewing. A comprehensive series of courses in higher technological instruction are also to be offered this year.

THE ANALYSIS OF CRYSTAL STRUCTURE BY X-RAYS.*

By PROFESSOR SIR W. H. BRAGG, K.B.E., D.Sc., F.R.S.

IN this address I propose to consider the new methods of analysing the structure of materials by means of X-rays, considering especially the stages by which they move towards their objective. It is convenient to recognise three such stages, of which the first comprises the simplest and most direct measurements and the last the most indirect and complex.

The fundamental measurement of the method is the angle at which rays of a given wave-length are reflected by a set of planes within the crystal. The planes of a "set" are all exactly like one another: an imaginary observer within the crystal could not tell by any change in his surroundings that he had been moved from one plane to another. Sometimes there is no reflection of the first order from a set so defined, because the planes may be interleaved by other planes so spaced and of such strength as to annul the true reflection; but this can always be allowed for. When the wave-length of the X-rays is known, the angular measurement can be used to find the spacing of the set of planes, and in this way a linear dimension of the crystal is measured. The spacing is the distance between any plane and its nearest like neighbour on either side. If the spacings of three different sets of planes are found, the volume of the unit cell is found. The crystal unit cell is bounded by six faces, each set of planes furnishing a pair. The pair consists of two neighbouring planes of the set.

The cell may have a great variety of forms, but has always the same volume. The specific gravity of the substance being known, it is possible to find the number of atoms of various kinds which the cell contains: the proportion of the various kinds is necessarily the same as in the molecule of the substance. The cell is in practice found always to contain a small integral number of molecules, one, two, three, or four, rarely more. The assemblage of molecules is fully representative of the crystal; by the mere repetition of the cell, without the addition of any new features, the crystal with all its properties is produced. There are, therefore, three types of assemblage. The simplest is that of the single atom, as in helium in the gaseous state, in which the behaviour of every atom is on the whole the same as the behaviour of any other. The next is that of the molecule, the smallest portion of a liquid or gas which has all the properties of the whole: and lastly, the crystal unit, the smallest portion of a crystal (really the simplest form of a solid substance) which has all the properties of the crystal. There are atoms of silicon and of oxygen: there is a molecule of silicon dioxide, and a crystal unit of quartz containing three molecules of silicon dioxide. The separate atoms of silicon and oxygen are not silicon dioxide, of course: in the same way the molecule of silicon dioxide is not quartz; the crystal unit consisting of three molecules arranged in a particular way *is* quartz.

The final aim of the X-ray analysis of crystals is to determine the arrangement of the atoms and the molecules in the crystal unit, and to account for the properties of the crystal in terms of that arrangement.

The first step is the determination of the dimensions of the crystal unit cell: any one of the possible ways in which the cell can be drawn will do. When this has been completed it is a simple calculation in geometry to find the distance between any atom and any other atom in the crystal of like kind and condition, or, in other words, the distance an observer would have to travel from any point within the crystal to any other point from which the outlook would be exactly the same and would be similarly oriented. This is the only measurement which the X-rays make directly: any other measurement of distance is made indirectly, by aid of some additional physical or chemical reasoning. It is not possible by direct X-ray measurement to determine the distance between any two points—atom centres, for example—within the same cell.

Let us take an example. The crystal unit of naphthalene has the dimensions defined in the usual way by the statement:—

$$a = 8{\cdot}34\ \text{Å} \quad b = 6{\cdot}05\ \text{Å} \quad c = 8{\cdot}69\ \text{Å}$$
$$\beta = 1{\cdot}22°\ 49' \quad \alpha = \gamma = 90°$$

It contains two molecules: an integral number, as always. These facts are given directly by the X-ray measurements. But there is no direct determination of the distance between any carbon atom and any other carbon atom contained within the same cell: the measurements given are those of the distances between any atom and the nearest neighbours, in three principal directions, which are exactly like itself, these distances being the lengths of the edge of the cell. There is not even a measurement of the distance between the two molecules in the same cell, because they are not similarly oriented. In fact, there is no clear meaning in the term "distance" in this case, just as we cannot state the distance between an object and its image in a mirror, unless the object is a point of no dimensions. If the molecule of naphthalene has a centre of symmetry, as is indeed indicated during the development of the results of the X-ray analysis, it is possible to state the distance between the centres of symmetry of the two molecules in the same cell, but this does not define the distance between any atom in one of the two molecules and any atom in the other. All such distances, if they are to be defined and measured, can only be found by the aid of fresh considerations.

Or again, let us take the case of rock-salt. The crystal unit cell of rock-salt contains one molecule: one form of the cell has for its eight corners the six middle points of the faces of a certain cube (edge = 5·62 A.U.) and two of the opposite ends of any diagonal of the cube. The so-called face-centred cube is four times as large as the cell, and contains four molecules. The dimensions of the cell are determined directly by the X-rays, which measure the distance between each of the three pairs of parallel faces that contain it. The cell may be placed so that each corner of it is associated in the same way with a molecule of sodium, let us say: and, of course, the knowledge of the dimensions of the cell is equivalent to a knowledge of the distance between any two sodium atoms in the crystal, which atoms are all alike in every respect. But we have no direct measurement by the X-ray methods of the distance between a sodium and a chlorine atom. We infer that the chlorine atom lies at the centre of the sodium cell, or *vice versa*, from considerations of symmetry. Crystallographic observations of the exterior form of the cell assign to the crystal the fullest symmetry that a crystal can possess. If the cell that has been described is to contain the elements of such full symmetry, the chlorine atom must lie at the centre of it. Moreover, both the sodium and the chlorine atoms must themselves contain every symmetry of the highest class; the full tale of planes of symmetry, axes of rotation, and so on. They both have centres, and we can state the distance between a chlorine atom and a sodium atom because we can state it as between centre and centre, and put it equal to half the distance between two sodium atoms on either side of the chlorine. The structure of sodium chloride is then determined completely.

Let us take one more instance—the diamond. The crystal unit cell contains two atoms of carbon; as in the case of rock salt, it may be so chosen that, of its eight corners, six are the middle point of the faces of a certain cube and two are the ends of any diagonal of the cube. The sides of this cell are determined by the X-rays, and are all equal to 2·52 A.U. This is the distance between any carbon atom and the nearest carbon atom which is exactly like itself. The distance between the two carbon atoms in the same cell is not measured directly, but can be inferred after it has been defined. This we are able to do because the carbon atom is tetrahedral; a tetrahedron has a centre, and we can state the distance between the centres of two tetrahedra, no matter how the tetrahedra are oriented. We know that the carbon atom, as built into the crystal, is tetrahedral, because the X-ray observations show that four trigonal axes meet in it. The two atoms in the cell are oriented differently; one may be said to be the image of the other, if translation shifts are ignored, in each of the faces of the cube. Considerations of symmetry or X-ray observations show that the centre of an atom of the one orientation lies at the centre of a tetrahedron formed by four atoms of the other orientation. The edge of this tetrahedron is the edge of the unit cell, and its length is 2·52 A.U. It may then be calculated that the distance between the one atom and the others, its nearest neighbours, is 1·54 A.U. We may call this distance the diameter of the carbon atom, but we must remember our original definition of the meaning of the term. Thus the 2·52 A.U. is the result of a direct unaided X-ray measurement, but the 1·54 A.U. is not, and has no meaning except after special definition.

Only such distances between atoms as can be calculated from the dimensions of the unit cell can be measured directly and without qualification. The determination of these distances may be looked on as the result of the first stage of the analysis by X-rays.

We now come to a second stage. It is possible to make other statements of the relative positions of atoms and molecules which, though less complete and informative than those of distances and their orientations, are necessary to the solution of the crystal structure problem. These also are deduced by means of the X-ray methods.

It often occurs that the atoms or molecules in one cell can be divided into two portions which are the reflections of one another across some plane, or can be brought to be the reflection of each other by a shift parallel to the plane. In that case the orientation of the plane and the amount of the shift can be stated definitely, the former by inspection of the crystal or by X-ray observations, the latter by X-ray observations alone. So also it may happen that the atoms or molecules in the same cell may be divided into portions which can be made to coincide with each other by a rotation round some axis with or without a shift parallel to that axis. The direction of the axis can be found by inspection of the crystal or by X-ray observations; the amount of the shift can be found by X-ray observations alone.

In these cases the distances that are found by the X-ray method are all that can be stated without special definition. It is not possible to state the distance between an object and its image in a mirror, if the object has any extension in space; but it is possible to state the magnitude of a shift.

Measurements of this sort constitute a characteristic feature of the X-ray analysis, for which reason I would like to discuss them briefly.

We know that it is possible to separate crystals into 32 classes, according to the kind of external symmetry which they display. As we have hitherto been unable to look into the interior of the crystal, we have been obliged to be content with this imperfect classification by outer appearance. It has been shown, however, that there is a classification by inner arrangement which is perfect and includes the other. It is beyond the limits of ordinary vision: out of the range of the lens and the goniometer. The interior arrangement of the crystal, of which the outer form is one consequence, is so varied as to furnish 230 different modes. With very few exceptions the X-rays now allow us to carry the classification to this higher degree. If the modes are grouped according to the external features of the crystals that follow them, we come to the well-known 32 classes, there being several modes in every class. I may be permitted to illustrate this important point by examples, although it is familiar to those who have studied crystallography. Let us consider first a two-dimensional example, which is much easier to describe than the three-dimensional actuality, and contains all the essential ideas.

Consider an arrangmeent of figures in a plane which displays symmetry across two planes at right angles to one another. Such arrangements may be exhibited diagrammatically, as in Fig. 1, page 350. The unit cell may be drawn in various ways, E F K J, E F L K, R S U T, and so on. The cell contains, however it is drawn, either a whole diamond or enough parts to make up a whole diamond. Each diamond can be divided into four parts: B and D are the reflections of A and C across a plane; C and D are the reflection of A and B across a plane at right angles to the first plane. Unless the diamond, the content of one cell, could be divided in this way there could not be the double symmetry. But, granted this division into four portions, it is not necessary that the four should be arranged as in the figure in order that the double symmetry may be obtained. There are two alternatives (Figs. 2 and 3).

In Fig. 2 the lower half of each diamond—that is to say, the portions C and D—are shifted, whether to right or to left is immaterial, by an amount equal to one-half of one side of the cell E F K J. The symmetry about a vertical line in the plane of the paper is obviously retained. It is not so obvious that there is still any symmetry about the horizontal line until we realise that we mean only "observable symmetry"; that which is to be seen in the outer form of the indefinitely extended figure, corresponding to the crystal. Clearly, the whole figure will present the same appearance from below as from above. In fact, we can see that as a whole the lower part of the figure is symmetrical with the upper part by imagining the upper and the lower to be further shifted relatively as in Fig. 2A, the two parts sliding on one another along the line S S. The two parts are then the image of each other across S S in the full sense of the word.

From Fig. 1 we may also realise that the amount of the original shift must be equal to one-half of E F; no other shift will give the symmetry which Fig. 2A shows. In Figs. 4 and 4A a different shift has been given, and the failure is clear.

In Fig. 4 not only are C and D shifted parallel to the horizontal line, but also B and D are shifted parallel to the vertical; this time the amount of shift is one-half of the side E J.

The three modes of Figs. 1, 2 and 3 all lead to the same external symmetry. There is one more which is based, as we should say, on a different lattice and is symmetrical, like the others, about two lines at right angles to each other. It is shown in Fig. 5. There are no variations of Fig. 5, as of Fig. 1, to be obtained by the introduction of shifts. If in Fig. 5 we shift C and D relatively to A and B, as we did in Fig. 2A, we find that they can now be described as the direct reflection of A′ B′ into C D and of A′C into B′D, and the mode of Fig. 5A is the same as that of Fig. 5.

* Abstract of Presidential Address to the Mathematical and Physical Science Section of the British Association at Toronto, August 11, 1924.

There are therefore four modes in one class: four varieties of internal arrangement which all lead to the same external appearance of symmetry.

Our example is two-dimensional and the crystal has three dimensions. But there are no new ideas to be added: it is only the numbers of symmetries, modes, and classes that are increased. If, for example, we continue the study of the modes of arrangement that lead to an external symmetry of reflection across two planes at right angles to each other, we find that there are four lattices instead of two, and 22 modes instead of four. The class containing crystals that possesses this particular form of symmetry is generally called the "hemimorphic class in the orthorhombic system." Its symbol is C_{2v}: the symbols of the four lattices are Γ_0 Γ_0' Γ_0'' Γ_0'''. In every case the content of the unit cell is divisible into four parts, corresponding to the A B C D of Figs. 1 and 5. The ten modes in the Γ_0 lattice are shown in Fig. 6, which will serve to show the numerical increase due to the introduction of the third dimension. Under each separate figure is given, beside the crystallographic symbol, another symbol which describes the shifts: D^x means a direct reflection across a plane parallel to yz; E^x_y a reflection across a plane parallel to yz, together with a shift parallel to the axis of y equal to half the y edge of the cell, and M^x a reflection across a plane parallel to yz, together with a shift parallel to the diagonal of the yz face and equal to half that diagonal.

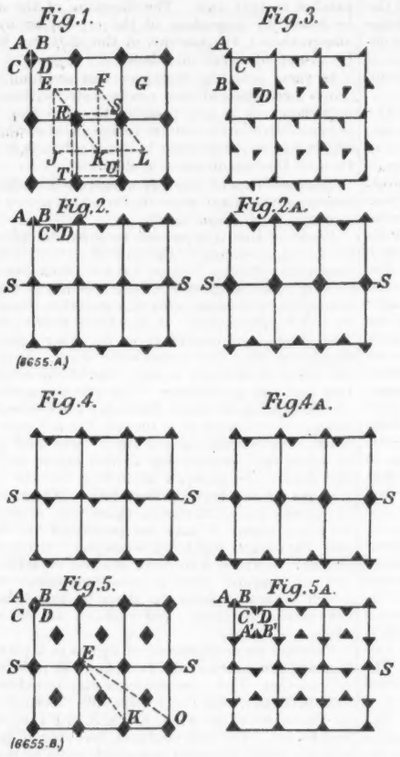
Let us now see how the X-ray analysis distinguishes the mode. Let us imagine that Fig. 1 represented a number of pits in a plane reflecting surface. The surface could be used as a grating having many spacings instead of one. If, for example, we so placed it that the horizontal lines of the figure were parallel to the slit of the spectroscope the spacing would be equal to E J: if the vertical, the spacing would be equal to E F. Again, if the grating were so placed that E K, for example, were vertical, the spacing would be the perpendicular distance between E K and F L. If the surface is pitted as in Fig. 2, the spacing when the horizontal line is parallel to the slit is the same as before; but when the vertical is parallel to the slit the effective spacing is only half what it was in Fig. 1. This follows from the fact that if we divided the surface into a number of vertical narrow strips the diffracting effect of each such strip, for this position, depends on the total amount of reflecting surface contained in the strip, but not on its distribution along the slip. It does not matter that C and D are upside down as compared to A and B. The strata consisting of C and D portions have interleaved the strata of A and B portions. This halving of a spacing of Fig. 2, as compared with Fig. 1, occurs only when the grating is placed so that the slit is parallel to the vertical line of Fig. 2, and not when any other line is vertical, except by some odd chance connected with the shape of the pits. In this way it is possible to distinguish between Fig. 1 and Fig. 2. The mode shown in Fig. 3 is distinguished by the halvings of both the horizontal and vertical spacings, and of no others. In the case of Fig. 5, as compared with Fig. 1, the spacing is halved when the slit is parallel to the horizontal or the vertical line of the figure, and also whenever the grating is so placed that the parallel to the slit passing through one of the corners of a cell does not pass through the centre of that of any other cell, as, for example, if E O, but not E K, is parallel to the slit. It is therefore easy to distinguish each of the four modes.

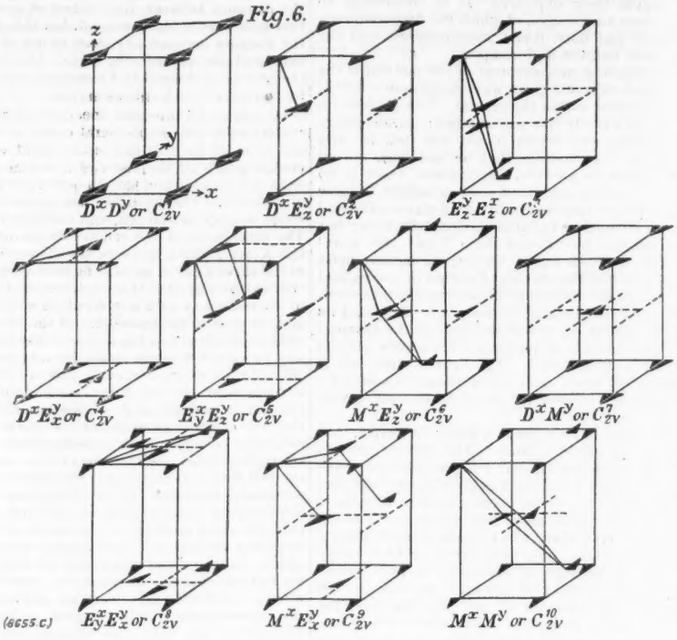
Similar methods are applicable to the three-dimensional crystal. If, for example, we consider the case of C^6_{2v} or $D^z E^y_z$ we can show that, whereas in general the spacings of planes are such as are proper to a cell of the dimensions and form drawn in the figure, all planes of the form $lx/a+mz/c$ = an integer, show halved spacings, unless l is odd and m is even: which is sufficient identification of the mode of arrangement. The symbols a and c denote edges of the cell.

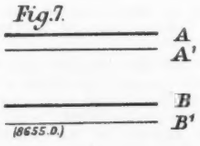
If we follow this line of reasoning through all the thirty-two classes, we end, of course, with the discovery of the 230 modes which are known to exist: and with the identification marks of each, with certain qualifications. These last are of two kinds. One of them is general in nature and is a consequence of the fact that the X-rays can measure only the distance between two like points in neighbouring cells, say A and B. But they do not indicate any difference that may exist between AB and BA. If such a difference exists it may be expected to show in the external characteristics of the cell, giving it polarity. A good example is to be found in zinc blende. Layers of zinc and of sulphur atoms alternate with one another as in Fig. 7, all of them being perpendicular to a trigonal axis of the crystal. The distance between a zinc atom in the layer A to a zinc atom in the layer B is found without question by the X-ray method. Now we know from observation of the crystal that there is a difference between AB and BA: the crystal is polar. A crystal plate cut so that its faces are perpendicular to the axis shows different properties on its two sides: if heated, one face becomes positively and one negatively electrified. Whichever face we use in the X-ray spectrometer we obtain the same value for the spacing, and we find ourselves unable to detect any difference between the two aspects by means of the spectrometer observations.

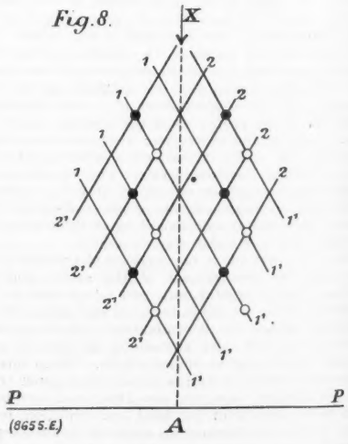
We may see this point in another way. Suppose that Fig. 8 represents a section of a crystal consisting of two kinds of atoms, indicated respectively by full and empty circles. The arrangement clearly has no symmetry about a vertical line in the plane of the paper. But if X-rays were incident from above, as shown, there would be equal reflections from the planes 11' and 22'. If the incident rays were heterogeneous and a photographic plate were placed to receive the Laue reflections in the usual way, there would be a symmetry distribution of spots on either side of A, although there is no symmetry in the crystal to correspond.

(To be concluded.)









ENGINEERS AND PROBLEMS OF PUBLIC INTEREST.—A change has taken place in the attitude of American engineers towards problems of public interest, says *Engineering News Record*, New York. Up to a few years ago, the individual engineer had no means of getting together with others in joint action to influence community of thought and action, and accordingly he made little or no attempt to exert such influence. The technical societies have always stood aloof from public affairs, and properly so, except where a well-defined technical problem was at issue. Organisations outside the technical field did not exist. Now, with two such organisations, viz., the American Engineering Council and the American Association of Engineers in existence, engineers realise their opportunity and responsibility. The study given to two important questions by the latter organisation during the past year exemplifies this; the relation of taxation difficulties to public works and the problems of land reclamation and settlement, were studied to good effect. The study of reclamation, in particular, was guided by insight and skill, and is sure to prove helpful in the ultimate adjustment of the subject. But reports of committees, be they ever so good, are likely to be of small effect unless made known to the community and urged upon legislators and officials.

THE CHANGES OF VOLUME OF STEELS DURING HEAT TREATMENT.*

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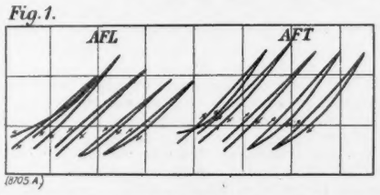
IN September, 1922,† the authors presented a number of test results dealing with the dilatation and contraction of air-hardening nickel-chromium steels during various and peculiar heat treatments. The present record deals with the extension of the series of tests previously recorded, which was primarily intended to investigate more particularly two points that had emerged during the initial series of experiments. The first of the matters that appeared to require careful consideration was whether the lateral expansion and contraction of the metal is equal to the longitudinal—*i.e.*, whether the steel expands and contracts as a truly isotropic material, or whether, as has been suggested, its behaviour in the two directions is different. The second point to call for further investigation follows from the fact that the results previously recorded were obtained upon specimens that had cooled in the dilatometer from the hardening temperature, and had therefore cooled at a fairly slow rate. In consequence, the specimens were in general not fully hardened, and therefore not really in a condition that could be accurately described as "air-hardened." It seemed important, therefore, to examine whether this method of cooling produced any difference in the subsequent dilatometric behaviour of the steel as compared with the same steel fully hardened.

The first of these points has been investigated by examining two forms of material from the same cast. The previous experiments had all been carried out on round bars. From the same cast of steel flat bars of a section 2¼ in. by ⅞ in. were rolled. From these flat bars test-pieces of the same dimensions as used previously were cut in two directions—*i.e.*, parallel to and perpendicular to the length of the bar. These pairs of specimens were treated and tested in similar ways, whilst a longitudinal specimen from the round bar previously used was also subjected to the same treatment.

Fig. 1.



The dilatometric behaviour of the fully hardened steel has been examined in two ways. In the first set of tests the specimens were heated in a separate furnace to the specified temperature, and then removed and hardened in the still air. They were then trued up very lightly and carefully, and examined during various treatments in the dilatometer. In the second method the specimens were hardened whilst in the dilatometer by cooling at a much more rapid rate than that formerly employed. This increased speed of cooling was brought about by passing a stream of compressed air through the tube of the dilatometer until the temperature of the specimen had fallen to that of the atmosphere. In order to avoid the oxidation of the specimens by the compressed air, they were copper-plated before being put into the instrument. The layer of copper on the sides of the specimens combined with the protective effect of the silica discs at the two ends of the specimens prevented any oxidation of the surfaces and consequently made the dilatometer records quite reliable. Specimens prepared in these two ways were therefore suitable for submission to the repeated tempering experiments that had been executed on the steels cooled slowly in the dilatometer, which formed the subject-matter of the former report.

All the experiments were carried out in the dilatometer previously described. The steel used had the analysis already reported, a considerable proportion of the experiments being made on specimens cut from the bars previously employed, whilst the flat bars were rolled from the same cast of steel. Unless it is otherwise recorded, the rates of heating and cooling in the present series of experiments were the same as those previously reported. In all respects, in fact, the second and first series of tests were made under similar conditions, except where a difference is specifically notified.

The actual experiments carried out to ascertain whether the longitudinal and lateral expansions of the steel were similar are described below. No such extensive tests as had been made originally appeared to be required in order to examine this point, and the tempering treatments were therefore only carried out at two temperatures—200 deg. C. and 600 deg. C. The specimens employed and the treatments given comprised the following :—

A.F.L.—Longitudinal specimen from the flat bar, heated in a separate furnace to 830 deg. C., hardened in air, then tempered in the dilatometer repeatedly at 200 deg. C. till no further change of length occurred. Five successive heats were required (see Fig. 1).

A.F.T.—Lateral specimen from the flat bar treated in the same way as A.F.L. Five successive temperings were required to produce a constant length (see Fig. 1).

A.R.L.—Longitudinal specimen from the round bar treated in the same manner as A.F.L. Three successive temperings were required to produce a constant length (see Fig. 3).

B.F.L.—Longitudinal specimen from the flat bar hardened like A.F.L. but tempered in the dilatometer repeatedly at 600 deg. C. till no further change of length occurred. Four successive heatings were required (see Fig. 2).

B.F.T.—Lateral specimen from the flat bar treated in the same way as B.F.L. Four successive temperings were required to produce a constant length (see Fig. 2).

Fig. 2.

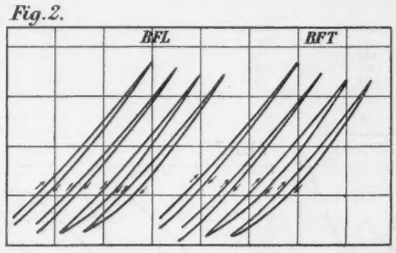
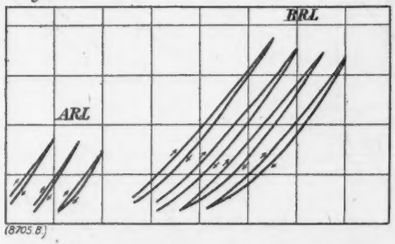


Fig. 3.



B.R.L.—Longitudinal specimen from the round bar treated in the same manner as B.F.L. Four successive temperings were required to produce a constant length (see Fig. 3).

A comparison of the behaviour of the three specimens tempered at 200 deg. C., or the set tempered at 600 deg. C., as shown in Figs, 1, 2, and 3, reveals the fact that there is no noticeable difference in the behaviour of the longitudinal and transverse specimens. The contraction of the different kinds of specimens is quite similar, and it would be difficult, if not impossible, to pick out any noticeable variation in the habits of either type of test-piece. From these experiments (which have been confirmed by numerous others made during the course of the work) it may be concluded with safety that the rolled steel behaves isotropically, and that there is no appreciable directional effect in its expansion and contraction. From this result it follows that the experiments described both here and previously may be taken accurately to represent changes of volume, although the changes actually observed are only those of length.

An extensive series of experiments has been carried out to provide the material for a comparison of the behaviour during tempering of the specimens cooled slowly in the dilatometer and those hardened in the air outside the instrument, and therefore cooled at the normal "air-hardening" rate. The specimens chosen for these tests were all taken from the round bar employed for the first set of experiments. In every experiment the specimens were machined to size plus a grinding allowance and then were hardened in the air. They were afterwards carefully ground on the ends and cleaned on the sides before being put into the dilatometer for testing. The hardening of all the specimens was carried out similarly amd simultaneously, and the temperature employed was 830 deg. C. A complete series of temperings was made at each of the following temperatures—100 deg., 200 deg., 300 deg., 400 deg., 500 deg., 600 deg., 700 deg., and 750 deg. C. The method of testing was the same as for the first series of treatments, the specimens being tempered by successive heating and cooling to the selected temperature until there was no further change in length. The specimens were not maintained at the tempering heat at all, but as soon as they had attained the specified temperature were allowed to cool again to the atmospheric temperature and then reheated if necessary. The results of the treatment given at the different temperatures are as follows :—

C.L.10.—Tempered at 100 deg. C., achieved constant length after four reheatings, the final length showing a contraction of 3 scale divisions from the hardened state.

C.L.20.—Tempered at 200 deg. C., the length became constant after three reheatings, the final length showing a contraction of 10 scale divisions from the hardened state.

C.L.30.—Tempered at 300 deg. C., the length became constant after four reheatings, showing a final contraction of 14 scale divisions.

C.L.40.—Tempered at 400 deg. C., the length became constant after three reheatings, the final length showing a contraction of 10 scale divisions.

C.L.50.—Tempered at 500 deg. C., the length became constant after three reheatings, the final length showing a contraction of 20 scale divisions.

C.L.60.—Tempered at 600 deg. C., the length became constant after four reheatings, the final length showing a contraction of 10 scale divisions.

C.L.70.—Tempered at 700 deg. C., the length became constant after three reheatings, the final length showing a contraction of 5 scale divisions.

C.L.75.—Tempered at 750 deg. C., the length became constant after three reheatings, the final length showing a contraction of 2 scale divisions.

Fig. 4.

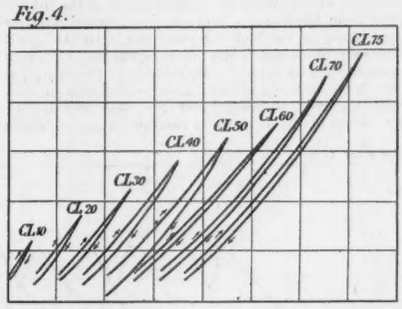
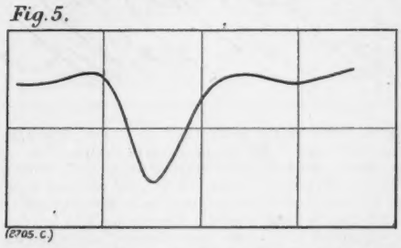


Fig. 5.



The first heating and cooling curves of the above specimens to their respective temperatures are shown in Fig. 4, and these can be compared with the curves in Fig. 3 of the previous paper.* In Fig. 5 is shown the volume at atmospheric temperature of the various specimens after once tempering at the different temperatures plotted against the tempering temperature. This curve can be compared with the corresponding curve shown in Fig. 4 of the previous paper.

One specimen, G.L.1, was treated by hardening in the dilatometer, being cooled from 830 deg. C. in 15 mins. This specimen was then tempered at 600 deg. C. until it attained to a constant length. This occurred after three heatings and coolings, and the net change of length was a contraction of 13 scale divisions. This is quite in accordance with the changes produced in the corresponding specimens hardened in air outside the dilatometer and then tempered in the instrument.

It is interesting to compare the net changes of volume brought about by the tempering of the specimens cooled in air herein reported and those cooled slowly in the dilatometer as reported in 1922. The values are shown in Table I.

TABLE I.—*Length Changes.*

Tempering Temperature. Deg. C.	Net Change of Length, Scale Divisions.	
	Air Cooled.	Dilatometer Cooled.
100	− 3	− 5
200	−10	− 6
300	−14	−15
400	−10	−15
500	−20	−16
600	−10	−15
700	− 5	—
750	− 2	—

It is evident from the figures given in Table I that but little difference is produced in the final behaviour of the specimens by the two treatments employed previous to the repeated temperings. The main difference is found in the route by which the specimen arrives at this final volume. In the specimens slowly cooled and tempered at the lower temperatures there is an expansion

* Paper read before the Iron and Steel Institute, London, on Thursday, September 4, 1924.

† See ENGINEERING, vol. cxiv, page 568.

* See ENGINEERING, vol. cxiv, page 568.

in the early stages of tempering which is not evident in the behaviour of the fully air-hardened specimens.

The third subject that was examined was the effect of cooling the steel from different temperatures. The experiments were varied in a good many respects in order to determine the effect of the various factors. The variants were the maximum temperature employed, the period of soaking at this temperature, and the rate of cooling therefrom. The temperatures varied between 830 deg. and 950 deg. C., the period of soaking between nothing and two hours, and the time of cooling from the maximum temperature between fifteen minutes and six hours. It is recognised that in the rapid cooling there is probably some small hysteresis between the volume records and the temperature readings. This is not likely to affect anything on the curves except the apparent temperatures at which the critical volume changes occur, and certainly not to affect the magnitude of the volume changes in any way.

The first series of curves was obtained by cooling specimens at the ordinary cooling speed of the dilatometer from the various temperatures chosen without any soaking at the high temperatures. All the specimens were hardened in the air from 830 deg. C. before being introduced into the dilatometer. The temperatures at which the specimens were treated were respectively 830 deg., 850 deg., 900 deg., and 950 deg. C. The curves obtained in these treatments are shown in

Fig. 6.

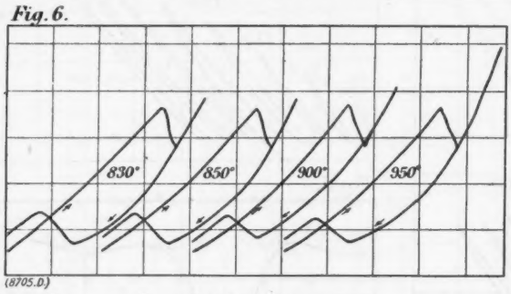


Fig. 6. The curves show that the effect of simply heating to and cooling from different temperatures is not greatly affected by the temperature actually chosen. The temperatures at which the critical changes occur are the same whatever the maximum temperature to which the steel was heated. There is a slight increase in expansion in the specimens heated to the higher temperatures, but this again is not very marked.

The next series to be considered is that of specimens treated at 850 deg. C., but cooled at different speeds and previously soaked for different periods. The series comprises the following specimens, all of them having been hardened in the air from 830 deg. C., before insertion to the dilatometer :

D.L.1.—Heated to 850 deg. C. in the dilatometer, not soaked, and cooled slowly.
D.L.2.—Heated to 850 deg. C. in the dilatometer, soaked for one hour, and cooled slowly.
D.L.3.—Heated to 850 deg. C. in the dilatometer, not soaked, and cooled in 15 minutes.
D.L.4.—Heated to 850 deg. C. in the dilatometer, soaked for 1 hour, and then cooled for 15 minutes.
D.L.5.—Heated to 850 deg. C. in the dilatometer, soaked for 2 hours, and cooled in 15 minutes.
D.L.6.—Heated to 850 deg. C. in the dilatometer, not soaked, and cooled in 30 minutes.

The curves illustrating the heating and cooling of all these series of specimens are shown collectively in Fig. 7. The curves indicate that differences in the period of soaking have a distinct effect upon the subsequent expansion of the material. When the steels are not soaked, and particularly when they are cooled slowly after no soaking, there is an expansion at the critical temperature to a volume even larger than that of the air-hardened material. When the material is soaked there is no such expansion, and the volume of the steel on cooling after such soaking is generally less than that of the specimen cooled in the air. The effect is rather striking.

The experiments corresponding with those shown in Fig. 7, but made by heating to other temperatures, comprised the following :

E.L.1.—Heated to 900 deg. C. in the dilatometer, not soaked, and cooled slowly.
E.L.2.—Heated to 900 deg. C. in the dilatometer, soaked for 1 hour, and cooled slowly.
E.L.3.—Heated to 900 deg. C. in the dilatometer, soaked for 1 hour, and cooled in 15 minutes.
F.L.1.—Heated to 950 deg. C. in the dilatometer, not soaked, and cooled slowly.
F.L.2.—Heated to 950 deg. C. in the dilatometer, soaked for 1 hour, and cooled slowly.
F.L.3.—Heated to 950 deg. C. in the dilatometer, soaked for 1 hour, and cooled in 15 minutes.

The curves obtained from the specimens heated to and cooled from 900 deg. C. are shown in Fig. 8, whilst those obtained at 950 deg. C. are shown in Fig. 9. The curves show that the steels when soaked for any prolonged period at the high temperatures employed for heating do not expand so much at the critical temperatures as when they are cooled at once. This applies to both the specimens heated to 900 deg. C. and those heated to 950 deg. C. ; whereas those cooled at once occupy a volume after reheating that is greater than the specimens hardened in the air from 830 deg. C. ; those soaked show a smaller volume. This applies to those that have cooled quickly and those that have cooled slowly. The effect is slightly more marked at 950 deg. than at 900 C., the latter temperature approximating rather more in its effect to that of 850 deg. C.

On these specimens treated for different periods at various temperatures and cooled at different speeds, tempering tests have also been made. The experiments have all been carried out at 600 deg. C., the specimens being reheated successively until the length became constant. The results of the tests on the specimens heated to 850 deg. C. are shown in Table II.

TABLE II.—*Tempering Tests.*

Soaking Time. Minutes.	Cooling Time. Minutes.	Number of Reheatings.	Change of Length. Scale Divisions.
nil	360	3	−12
60	360	1	nil
nil	15	3	− 9
60	15	3	− 5
120	15	1	nil

Fig. 7.

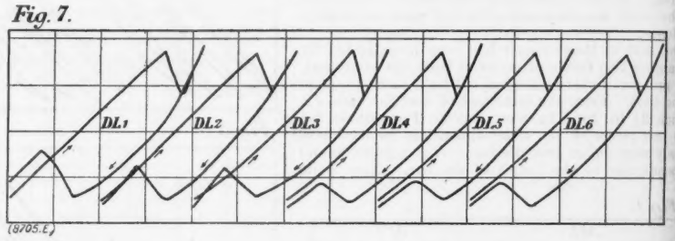


Fig. 8.

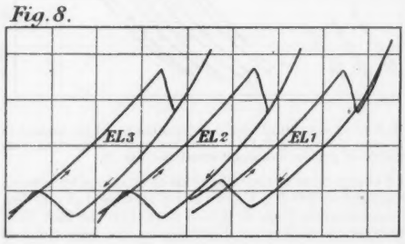


Fig. 9.

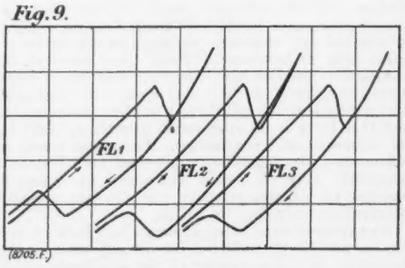


TABLE III.—*Tempering Tests.*

Soaking Time. Minutes.	Cooling Time. Minutes.	Number of Reheatings.	Change of Length. Scale Divisions.
nil	360	2	−12
60	360	1	nil
60	15	1	nil

TABLE IV.—*Tempering Tests.*

Soaking Time. Minutes.	Cooling Time. Minutes.	Number of Reheatings.	Change of Length. Scale Divisions.
nil	360	2	−10
60	360	1	nil
60	15	1	nil

It would appear from the results in Table II that if the specimen has soaked at the high temperature for a prolonged period the resulting article is not very prone to any subsequent change of length on tempering. If the cooling is very rapid there may be a change of volume on tempering, but if the soaking has been long enough the effect of the rapid cooling is counteracted. Both soaking and slow cooling reduce the subsequent volume change on tempering, and the soaking appears to be able to neutralise in a measure the rapid cooling. The absence of soaking is not, however, compensated for entirely by slow cooling.

The corresponding effects of tempering those specimens that were variously treated at 900 deg. C. and 950 deg. C. are given in Tables III and IV respectively.

It would appear from these tests that heating to temperatures above 850 deg. C. has an effect similar to that of increasing the period of soaking at the lower temperature. This result might reasonably be expected.

The principal conclusions that can be drawn from these experiments (apart from the previously mentioned conclusion that the longitudinal and lateral expansions are the same) appear to be connected with the formation and stability of austenite and the considerable sluggishness of the formation of sorbite. The fact that the exposure of the steel to higher temperatures, and particularly the fact that prolonged exposure produces a state of the metal which expands less on cooling either quickly or slowly, is probably associated with the production of a thoroughly stable austenite—or maybe that only such a treatment produces austenite completely. The austenite produced under these conditions is more stable and appears to change to martensite rather reluctantly (hence the smaller expansion).

The low-temperature heatings undoubtedly cause, first of all, a more complete martensite change—causing therefore an initial expansion—and then the gradual breakdown of the martensite by the agglomeration of the carbides that are thrown out of solution produces a contraction. This is the main and final result of the tempering. The heating to lower temperatures, of course, does not produce the same degree of contraction as tempering at 600 deg. C. This is found to be true of all the experiments, some of which are not reported herein. It is noted that the specimens cooled slowly in the dilatometer and then reheated to low temperatures expand and finally contract. Those cooled in the air and then tempered, however, contract from the start, and finally arrive at the same volume as those slowly cooled. No explanation of this difference, which is thoroughly well authenticated by numerous experiments, can be suggested.

The apparent stability of the specimens soaked at high temperatures and then tempered at 600 deg. C. is partly due to the high tempering temperature. The small contraction of the specimens hardened in air and then tempered at 700 deg. C. or 750 deg. C. suggests that the Ac point starts at a low temperature and is well spread out in these steels.

It appears fairly certain that air-hardened nickel-chromium steel as ordinarily heat-treated is by no means in a stable volume condition. By hardening from a high temperature and soaking well greater stability can be introduced, but, after ordinary hardening, the tempering must be extended for a long time in order to produce complete stability of dimensions.

A NEW TRANSFORMER OIL.—Users of transformer oil may be interested to know that Messrs. Shell-Mex, Limited, have recently put upon the market a new water-white hydrocarbon oil of a particularly non-hygroscopic character, which more than complies with the British Engineering Standard Association's Specification No. 148 for Class "A" transformer oil (light grade). The oil, which is known as "All's Well Transformer Oil K.I.," is to all intents and purposes sludgeless, while its disruptive strength is more than double the value demanded by the specification. The latter requires a disruptive strength of not less than 22,000 volts for a 0·15 in. spark gap between ½-in. electrodes, while the actual value obtained on test with the new oil was 45,000 volts. The oil has a lower viscosity, a lower evaporation loss and a rather higher flash point than are called for by the specification, according to tests carried out by Messrs. Michie and Davidson on an ordinary sample taken from stock.